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ESCUELA POLITÉCNICA SUPERIOR

GRADO EN INGENIERÍA DE LA ENERGÍA

BACHELOR THESIS

ATLAS OF ELECTRICAL INDICATORS PUBLISHED IN SPAIN AND THE EU

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Chapter 1.- ABSTRACT

This bachelor thesis focuses on the compilation of the most important electrical indicators both at a national and international level. Since electricity is essential to our lifestyle, the analysis of these indicators provides with a solid basis for understanding the main characteristics of the electrical system in each country and the most notable differences and similarities across them.

In addition to selecting and analysing these indicators based on data provided by several agencies, a comparison is made between different countries in order to get a more global idea of the components of the electrical system and the parameters that evaluate it. The countries on which the comparison and analysis are made are: Spain, Germany, France and the United Kingdom.

Furthermore, it is intended that these data and statistics, as the most relevant for describing an electrical system and showing a global view across countries, are presented in a single document as well as incorporated in a tool which encompasses them. For this purpose, the tool developed is a webpage, which being free-access and user-friendly allows to quickly locate a specific or several indicators for future analysis, research or curiosity of the user.

Key words

Electric system, electrical indicators, generation, network, consumption, electricity market, European comparison, webpage.

Computer tools

Microsoft office Word 2013, Microsoft office Excel 2013, web design creator wix.

Este trabajo de fin de grado se basa en la recopilación de los indicadores eléctricos de mayor interés tanto en el ámbito nacional como a nivel internacional. Dado que la electricidad es fundamental en nuestro estilo de vida, el análisis de estos indicadores supone una base sólida para la comprensión de las principales características del sistema eléctrico en cada país y sus más notables diferencias y similitudes.

Además de seleccionar y analizar dichos indicadores a partir de los datos provenientes de diferentes agencias, se hace una comparación entre países con el objetivo de obtener una idea más global de los componentes del sistema eléctrico y los parámetros que lo evalúan. Los países sobre los cuales se realiza el análisis y la comparación son: España, Alemania, Francia y Reino Unido.

Además, se quiere que los datos y estadísticas considerados como más relevantes y útiles a la hora de describir el sistema, se incorporen en un mismo documento así como en una herramienta que lo englobe. La herramienta desarrollada es una página web, la cual siendo de libre acceso tiene por finalidad la rápida localización de los diferentes indicadores para futuros análisis, investigaciones o simplemente por curiosidad del usuario.

Palabras clave:

Sistema eléctrico, indicadores eléctricos, generación, redes, consumo, mercados eléctricos, comparación Europa, página web.

Herramientas utilizadas:

Microsoft office Word 2013, Microsoft office Excel 2013, diseñador de páginas web wix.

Chapter 2.- INTRODUCTION

Energy is essential for people and the most versatile energy nowadays is electricity, as it is the one allowing for the occidental world to function. Thus, the knowledge regarding every factor which is involved in the process that goes from electricity's generation or production to its final consumption as well as its distribution and demand, becomes fundamental for the objective of obtaining a global insight of a certain territory's electrical system. These factors are published by several national organizations and institutions within each country. Nevertheless, in this globalised world that we are part of, it is proved necessary that they are all integrated and available altogether so that studies, comparisons and conclusions can be drawn across countries in order to achieve a better management of resources.

This is therefore the aim of this paper, and the understanding of the electrical system is provided by means of the so called "electricity indicators", which must be adequate and allow for a general view of an electrical system to be obtained. They are able to provide both a quantitative measurement and a qualitative observation in such a way that systems can be compared across countries and differences between them can be deeply analysed and addressed.

Consequently, an Electricity Indicators Atlas is elaborated and further explained in this report, being the election and definition of such indicators a determinant factor of the project in order to choose the most representative and relevant ones so that accuracy at analysing an electrical system is obtained.

According to this, this paper will show data on the electric systems of Spain, Germany, France and the United Kingdom, for the years 2012-2016.

Furthermore, this information is organized and displayed in a web page which has been designed and established as one part and final purpose of this project.

2.1 Objectives

The objectives of this work are the following:

- To make an overview of the most important electric components that take part in the daily work of the electric system of a country, physical and organizational elements with Spain as a model.
- To stand out the most significate data of the electric system
- To implement a web page where everyone who needs it can access to and compare the most important statistics and information of the electric system of Spain, France Germany and the United Kingdom.

2.2 Structure

Without taking into account this chapter, the project is divided in 10 chapters.

Chapter 3 - Electrical system in Spain

In this chapter there is a brief introduction of the electric system with an explication of its mainly different parts: generation, transmission, consumption and demand and markets. There is also a description of the principal agents that take part and control of the system with examples of the Spanish case to understand all of it better.

Chapter 4 - Electrical indicators

In this chapter there is the presentation of the electricity indicators, explained in a general way their meaning and exampled with the source where they are found.

Chapter 5 - Atlas development

In this chapter there is where the selection of the main and most important indicators are chosen and then classified each one by country. There is where each country has their own indicators referring to diverse years from 2012 to 2016 (most recent information found for each country).

Chapter 6 - Computer tool

In this chapter is where the computer application is presented, in this case a web page has been implemented and explained with an example case and in a high visual way to an easier interpretation for the user.

Chapter 7 - Activity schedule

Chapter 8 - Costs

Chapter 9 - Conclusions

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Chapter 11 - Acronyms list

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Chapter 3.- ELECTRIC SYSTEM IN SPAIN

The electrical system is the interconnected network aimed at delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centres, and distribution lines that connect individual customers.

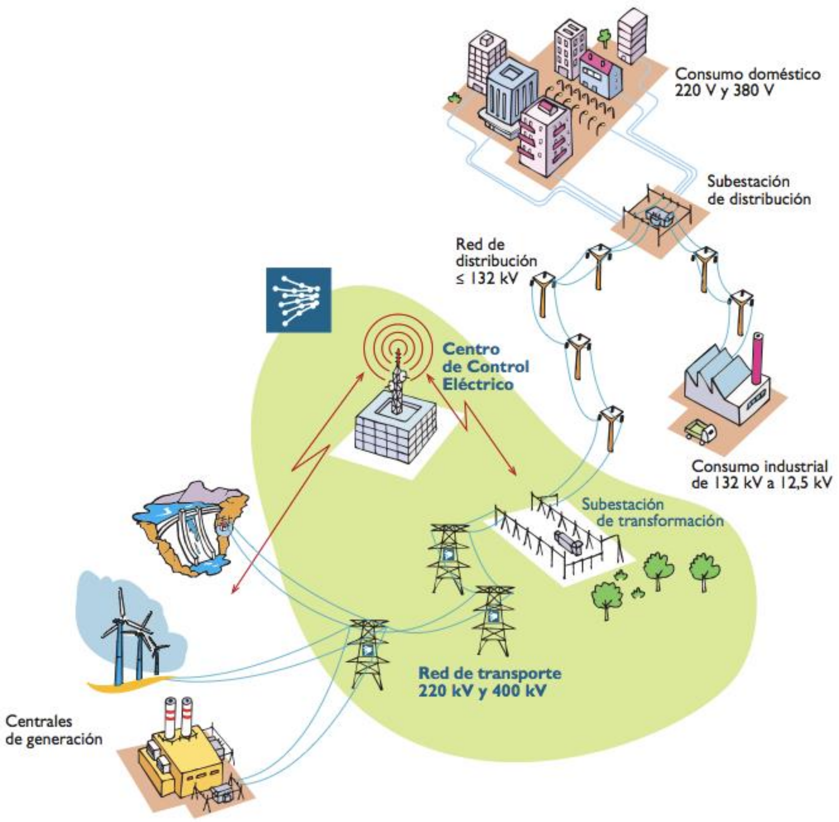


Figure 1: Overview of the electrical system of Spain. Source: eneregiaysociedad from REE (1).

Nowadays, although there exist different ways to storage electricity, with different physical storage principles like mechanical (the pumping water system), thermal, electrochemical or electromagnetic, the fact is that there is not an efficient and effective way to keep big amounts of electricity stored yet.

This leads to complexity and obstacles, as therefore the electricity that is consumed needs to be generated at the same moment. This is why an accurate system which is able to match both consumption and generation is required, since the demand is "unpredictable", this means, it varies constantly within the year and day, and forecasts are not entirely exact.

The graph below, as an illustration of this fact, shows how the demand changes in Spain, ranging from 37500 MW to 22500 MW within a day, being the yellow line the demand, the green line the forecast and the red one the programmed:

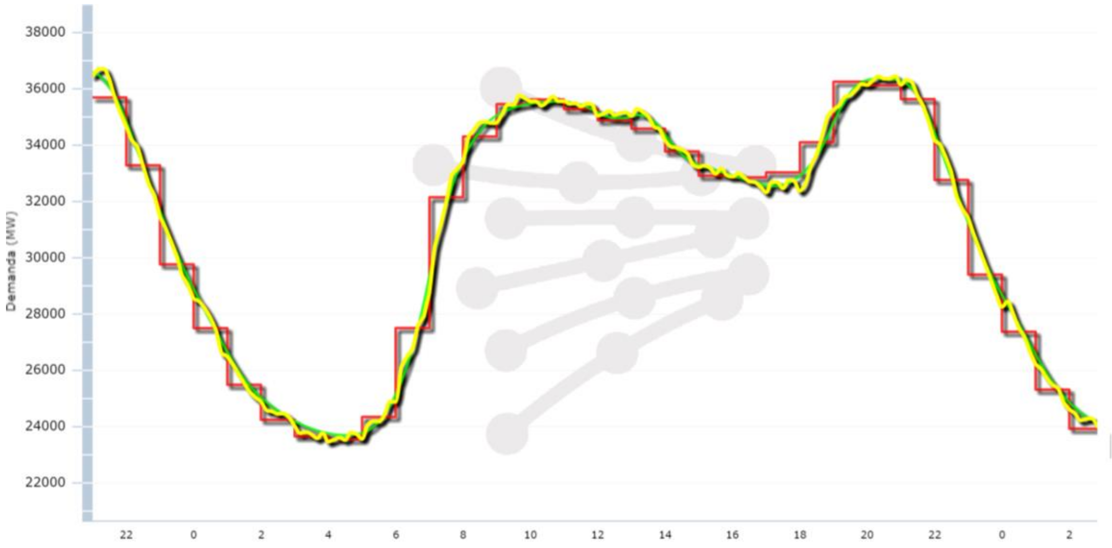


Figure 2 Demand curve REE 2017-02-01. Source: REE (2).

On the one hand, to anticipate the demand curve, the electrical system needs to make a lot of estimations based on historical data and different factors such as temperature or big events to predict with the highest precision the amount of electricity that will be demanded.

On the other hand, the system has also to select the *generation mix* that will be in charge of fulfilling that demand. It becomes a hard task due to the volatility of different sources of energy, mainly renewable energy since it is dependent on weather conditions such as wind or sun, which makes it impossible to be predicted with no more than a few days in advance.

Thus, in order to face this challenge, the role of the transmission system operator or TSO is needed.

To face this challenge this new agent is needed to manage the fulfilment of demand. The operation of the system encompasses the activities necessary to ensure the security and continuity of supply, as well as the proper coordination between production and transmission, ensuring that the energy produced by the generators is carried to distribution networks under the quality conditions required by the regulations currently in force. (3)

In the next chapter it will be explained all the required information related to the electrical system from the generation.

3.1 Generation

Generation refers to the processes which transform a natural resource into electricity power, including both the traditional ways with limited sources such as coal, gas and oil, and the so called renewable energies obtained from unlimited energy sources.

Generation sources

There exist different ways of generating energy, as it is explained above:

- Thermal power

Thermal power plants work principally with fossil fuels like oil, coal or gas. The combustion of the fuel is used to heat a fluid that moves a turbine connected to a generator that produces electricity. They belong to the previously mentioned traditional sources of electricity.

- Combined cycles

Combined cycles are the result of joining a Bryton cycle and a Rankine cycle. The mix of both of them increases significantly the efficiency from a 30% in the Bryton and 40% in the Rankine cycle separately up to a 55% with the new combined system. More and more combined cycles are being built in many countries. Its bigger advantage is its fast response to system operator orders either to produce electricity when it is required or to consume reactive power produced by the system.

- Nuclear energy

Nuclear energy is the energy which is contained in the nucleus of an atom. Atoms are the smallest particles in which a chemical element can be divided into and still maintain its properties. At the core of each atom there are two types of particles (neutrons and protons) that hold together and nuclear energy is the energy that holds them together. The high amount of energy released from the fission of the atom is used to heat a fluid in charge of moving a turbine connected to a generator.

Nuclear power energy is a very controversial way of generation of electricity. It is a very political influenced technology, which explains the big difference in its weight within the production of electricity when comparing different countries. Despite this, it is one of the cleanest ways of generating electricity in terms of amount of waste (only the radioactive material used is waste), the riskiness of this radioactive material make them very delicate. Also the possibility of an accident like the ones that happened in Chernobyl or Fukushima makes a big part of the public opinion to go against it. (4)

- Hydroelectric power

Hydroelectric power plants use the kinetic and potential energy of the water, mainly in a dam, to move a turbine connected to a generator. The dam allows to control the production of energy by letting to pass more or less water. In some hydroelectric stations there exists the possibility to storage electricity by transforming it into potential energy by pumping water to a higher place. (5)

- Wind energy

Wind power is kinetic energy of wind exploited for electricity generation in wind turbines. Wind energy, like other power technologies based on renewable resources, is widely available throughout the world and can contribute to reduce energy import dependence. As it entails no fuel price risk or constraints, it also improves security of supply. It can be onshore or offshore, depending on the location on land or on the sea where the space and the air density allows to install bigger turbines with bigger capacity of generation.

- Solar energy

Solar photovoltaic (PV) systems directly convert solar energy into electricity. It is the only technology that do not use turbines in the process of electricity generation. The basic building block of a PV system is the PV cell, which is a semiconductor device that converts solar energy into direct-current electricity. PV cells are interconnected and form a PV module, typically up to 50 to 200 Watts. The PV modules, combined with a set of additional system components (e.g. inverters, batteries, electrical components, and mounting systems), form a PV system. Modules can be linked together to provide power ranging from a few watts to hundreds of megawatts.

Also, Concentrating solar power (CSP) devices concentrate energy from the sun’s rays to heat a receiver to high temperatures. This heat is then transformed into electricity.

- **Other sources**

Other sources include principally renewable methods of generating electricity. There is more and more developing and improving of new ways of production, as it is the case of biomass that uses the residues, the energy produced by the waves or the heating that is in the centre of the earth.

The table below, as an example, shows the evolution of installed power capacity in the Spanish peninsula: the maximum capacity is practically stagnant since 2012. However, it can be observed that, while the hydro, the nuclear and the coal did not vary, the combined cycle and the renewables, and especially the wind energy ,increased their weight.

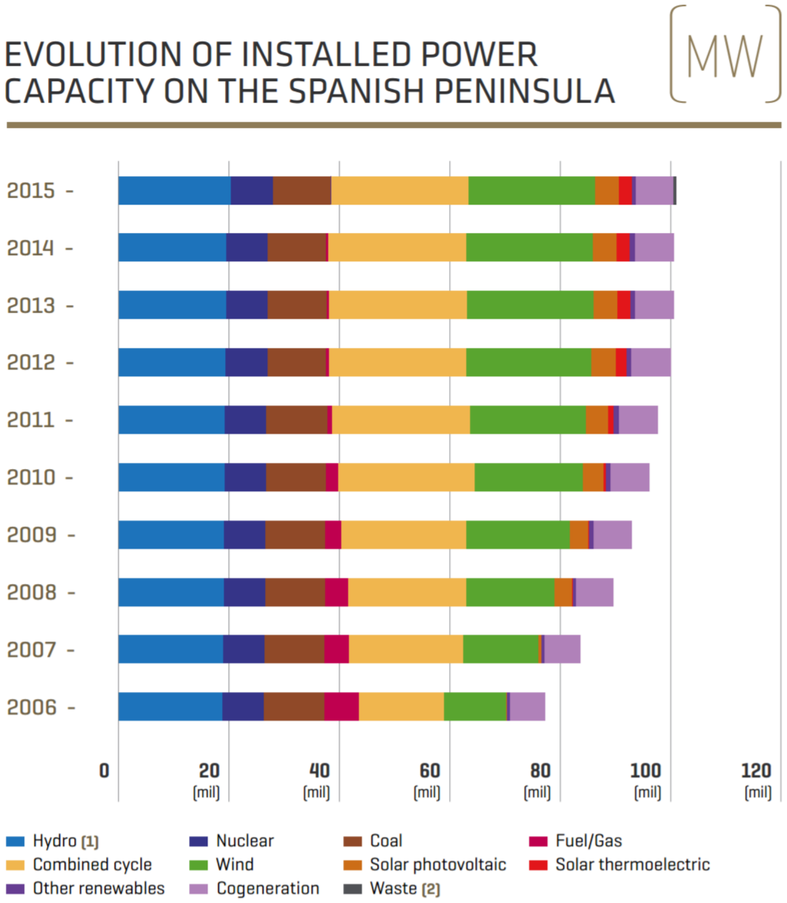


Figure 3: Evolution of the installed power capacity of Spain. Source: REE (6)

<u>Waste generation</u>

Nowadays all the energy sources are not completely clean. This means that they all generate wastes in a different way and quantity. It has to be considered that all the building machines and all other issues have to be manufactured and in that process there are always waste and pollutants.

The different types of pollution can be divided into two different groups: “matter waste” and “nonphysical waste”.

The first one refers to all the residues in the energy production process that cannot be used anymore, including all the gases and the materials that go to different types of dumping sites. It also includes all the pollution referred to the ashes and all the radioactive material produced by the nuclear stations (for example).

On the other hand the nonphysical waste is the sum of the all the pollutants that cannot be considered matter causing for example sound or view impact, it also includes how a new plant location affect the ecosystem (wind turbines and birds as an example).

Availability rate and response velocity

It is important to emphasise as it has been mentioned before the importance of the concepts of availability rate and also the response velocity.

Availability rate corresponds to the percentage of time that the power station is able to produce electricity of the total time, being the renewables technologies the most unstable ones due to the weather variations.

Response velocity corresponds to how fast the answer is to an instantaneous demand of electricity (nuclear energy for example needs days or even weeks to start producing electricity or to stop producing it while the hydro or the combined cycle productions are very fast).

3.2 Network

To carry the electricity the system must have a solid infrastructure with high security and coordination to achieve the desired objective (7).

The infrastructure used can be divided in overhead lines and substations.

Overhead power lines

The main components of overhead power lines are the conductors, the insulators and the transmission towers:

- **Conductors'** mission is to carry electric current and most of them are made of aluminium and steel (ACSR). They consist of several threads disposed in layers. Outer strands are made of aluminium and provide a path for the electric current. Inner strands are made of steel, to support the weight of the conductor without stretching the aluminium strands. The strength of steel complements the properties of aluminium, which is cheap, light and with good conductivity.
- **Insulators** fulfil two functions: supporting the conductors and withstanding voltage across them. Traditionally they are made of porcelain or glass (insulating material), but composite insulators are a different technology that has been increasingly used during the last decades.
- **Transmission towers**, also called pylons, are the structures that support overhead lines over the ground. They can be made of wood, concrete, tubular steel or lattice.

The main difference between transmission and distribution grid (mainly lines) is the voltage level: while the transmission line is usually referred to high voltage level (to cover big distances with less loses), the distribution grid is used for the medium and low voltages.

In the case of Spain the transmission system is the result of the combination of all the lines, substation or any electric element with voltage level higher than 220kV. On the other hand the distribution system is represented by all the elements with less than 220kV of voltage level.

Substations

Substations link different lines in power systems and provide with protection and operation flexibility. They can be classified in open-air substations, in which atmospheric air acts as an insulator between busbars, and compact substations, in which some other insulator is used to reduce the distance between conductors and the footprint of the complete substation.

The main components found in a substation are: busbars, transformers, circuit breakers, isolation switches or disconnectors, surge arresters and voltage and current instrument transformers.

3.3 Demand and consumption

Regarding demand and consumption, first of all it is important to differentiate both terms: Demand is always bigger than consumption, as it refers to the energy ordered to the power stations while consumptions refers to the final energy that users get.

The main difference between them is the result of the losses in the transmission and distribution lines. The difference is around 10-15% and it varies depending on the voltage level, being in the transmission grid (high voltage) where the losses are the lowest.

3.4 Electricity market

In Spain, as it happens in some other countries, there are a many participants within the electricity market that starts to work much time before the day the electricity will be consumed. Therefore the market can be divided into spot daily and intraday market depending on when would be the dispatch of that electricity. The whole market is organized as follows:

MIBEL

The Iberian Electricity Market or MIBEL resulted from the cooperation between the Portuguese and Spanish Governments with the aim of promoting the integration of both countries' electrical systems. The consequences thereof made a significant contribution not only towards establishing an electricity market at the Iberian level but also at the European level as an important step towards establishing an Internal Energy Market. It brings benefits to the consumers of both countries within a framework for providing access to all interested parties pursuant to the terms of equality, transparency and objectivity (8).

OMIP

OMIP is the Iberian exchange of electricity derivatives, which ensures the management of the market together with OMIClear, which assures the functions of Clearing House and Central Counterpart of the operations carried out in the market. (9)

The main objectives of OMIP are:

- Contribute to the development of the electricity market

The existence of an efficient derivatives market is crucial for the development of the electricity market, offering conditions to participants, irrespective of their size, geographic location or type of activity, to increase their degree of competitiveness in the electricity sector.

- Promote Iberian reference prices

The activity and prices generated in OMIP now represent key indicators for the development of economic activity around energy, supporting market liberalization.

- Facilitate efficient risk management tools

The main reason for the existence of derivative contracts is to be able to meet the needs of coverage of price variation risks, and OMIP's objective is to provide efficient instruments for the management of such risks. The market model allows institutions with know-how in the field of risk management to play a part in this important role, either on their own account or on behalf of third parties.

- Facilitate an appropriate market model for all actors

OMIP offers a liquid and transparent market, which benefits from anonymity in the negotiations, as well as the intervention of OMIClear as Central Counterpart of all operations. Taking advantage of the infrastructures and the know-how acquired, OMIP has extended its services to primary energy emissions (VPPs), sale auctions and purchase auctions of natural gas, auctions for the attribution of wind production licenses, in addition to performing the functions of manager of the process of change of supplier of natural gas (10).

OMIE

The management of the Iberian electricity spot market is the responsibility of the operator of the Iberian Energy Market, which began operations in 1998.

In the electricity spot market, transactions are carried out, with physical delivery, resulting from the participation of the agents in the daily and intraday market sessions that combine, in a market splitting logic, the Spanish and Portuguese zones of MIBEL.

Daily market trading takes place on the basis of a daily auction, with settlement of energy at all hours of the following day. Thus, a single price is established for Spain and another for Portugal for each hour of the following day. These prices may be different, in particular where, for a given time, the interconnection is congested, i.e. not sufficient to ensure all electricity transits between the two regions.

In addition, there are several intraday market sessions, following the daily market auction, where it is possible for agents to trade electric power for the various hours of the day covered by that market. The mode of trading is also by auction.

The financial settlement of the operations takes place on a weekly basis, subsequent to the delivery of electricity, and guarantees are provided.

Producers, self-producers, external agents (non-resident status), marketers, representatives and qualified consumers may be spot market agents. With the entry into force of the International Agreement signed in Santiago de Compostela on 1 October 2004, entities authorized in Portugal will be able to act on the spot market, benefiting from automatic recognition, and will no longer be considered as external agents (11).

3.5 Agents, regulatory bodies and authorities

In Spain there are different organisms in charge of the regulation of the electricity sector. The main authorities are the Ministry of Industry, Energy and Tourism, the National Commission of Markets and Competition and the various energy departments of the different autonomous communities. They are responsible for regulating the activity of Red Eléctrica, as well as assessing its management and establishing the remuneration for their services.

Ministry of Energy

The main objectives of the energy minister include the security in the energy supply, the competitiveness in the energy markets and the protection of the environment.

In the Spanish case the MINETAD ("Ministerio de Energía, Turismo y Agenda Digital") group different organizations such as regulatory bodies (CSN) public entities (IDEA) or autonomous bodies.

National commission of markets and competitiveness

The "Comisión Nacional de los Mercados y la Competencia" (CNMC) is the body responsible for the supervision and inspection of Spanish markets and the activity of all those involved in them (12).

The aim of the CNMC is to promote and defend proper functioning of all markets, in the interest of consumers and businesses.

The CNMC is subject to parliamentary oversight, which ensures its independence and increases legal security.

Nuclear Safety Council (Consejo de Seguridad Nuclear)

As in other countries, there exists a special organism in charge of the nuclear sector. This body ensures the safe operation of nuclear and radioactive facilities by establishing preventive and corrective measures against radiological emergencies, whatever their origin is.

System operator

The operation of the system encompasses the activities necessary to ensure the security and continuity of supply, as well as the proper coordination between production and transmission, ensuring that the energy produced by the generators is carried to distribution networks under the quality conditions required by the regulations currently in force. In Spain the system operator is REE.

Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente.

At last, the "Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente" proposes and implements government policy in relation to climate change and environmental protection.

Chapter 4.- ELECTRICAL INDICATORS

The following pages present the most interesting electric indicators published by the different organisms.

In order to do such selection they have been divided in four groups, which are generation, network and infrastructure, consumption and demand, and market and prices:

- Generation refers to the production of electricity in the power plants.
- Network and infrastructures refers to the mechanisms in charge to carry that electricity from the power stations to the consumers.
- Consumption and demand refers to the energy in the form of electricity that is consumed by the clients.
- Market and prices refers to those indicators relative to the economy related to electricity.

4.1 Types of indicators

4.1.1 Generation

Installed power capacity (GW)

It is defined as the maximum electric (power) output a country can produce at a certain moment under certain conditions, such as that all the power plants work at their maximum capacity. Some of those include (5):

- The temperature of cooling water for thermal power plants or the temperature of the atmosphere air for combustion turbines.
- The water flow and reservoir storage characteristics for hydropower plants
- The weather condition such as wind for wind turbines or sun for photovoltaics
- The availability of the power plant due to maintenance or any kind of mechanical or technical decisions

E.g. for Spain at 31-12-2010 the installed power capacity was 101,830 MW (6)

Electricity generation capacity per million of heads (W/hab)

It is the maximum electric (power) output per capita a country can produce at a certain moment with determined conditions such as that all the power plants work at their maximum capacity.

E.g. for Spain at 31-12-2012, the electricity generation capacity per capita was 2,108.89 W/hab

Installed power capacity distribution (%)

It is defined as the share between the different sources of electricity for the maximum power capacity of a country for a certain moment. Those technologies are: hydro nuclear fossil fuels renewables (solar and wind) and others.

E.g. for Spain at 31-12-2012 installed power capacity distribution was:

TECHNOLOGY	%
HYDRO	19.40%
NUCLEAR	7.70%
FOSSIL FUELS	35.90%
RENEWABLES (SOLAR WIND)	28.40%
OTHER	8.60%
TOTAL	**100.00%**

Figure 4: Power capacity distribution Spain 2012. Source: REE (13), own development.

Annual electricity production (GWh)

It refers to the amount of electricity produced during a specific year in a country, i.e generated by its power plants (measured at the exit of the power stations).

E.g. for Spain for 2012 the annual electricity production was: 268502 GWh

Annual electricity production per capita (kWh/hab)

It refers to the amount of electricity produced during a specific year in a country per habitant.

E.g. for Spain at 31-12-2012 annual electricity production per capita was: 5,735.02 kWh/hab

Annual electricity production distribution (%)

It is defined as the share between the different (technologies) sources of electricity of the annual production for the following ways of generation: hydro nuclear fossil fuels renewable (solar and wind) and others.

E.g. for Spain for 2012 annual electricity production distribution was:

TECHNOLOGY	%
HYDRO	7.70%
NUCLEAR	22.10%
FOSSIL FUELS	33.40%
RENEWABLES (SOLAR WIND)	22.30%
OTHER	14.50%
TOTAL	**100.00%**

Figure 5: Annual electricity production distribution Spain 2012. Source: REE (13), own development.

CO_2 emissions (tonnes of CO_2)

It is defined as the quantity of CO_2 emissions related to the production of electricity in a country during a year.

E.g. for Spain for 2012 emissions was: 80 million of tonnes.

Integration of renewables (%)

It defines the impact of the renewable generation respect to the total electricity generation in a country as a percentage.

E.g. for Spain at 31-12-2012 integration of renewables was: 31.90%

4.1.2 Network and installations

Network length (km)

It refers to the longitude of the grid. It could refer to the distribution length or to the transmission length.

E.g. for Spain at 31-12-2012 the total length of the transmission grid was: 38530 km

Investment (million €)

When talking about the grid, it is the quantity of money used in the electricity network. It could be used for the transmission grid or the distribution one.

E.g. for Spain at 31-12-2012 the total investment in the transmission grid was: 672 million €

There are 3 indicators that are referred to the quality of the global transmission system. All of them are related to the interruption time, the number of interruptions and the frequency and voltage. (14)

Grid availability (time %)

Percentage of the total time along one year where all the elements of the system such as lines transformers and control elements are available to work.

E.g. for Spain in 2012 the grid availability was: 97.8%

Energy Not Supplied, ENS (MWh)

It measures the energy not given to the system because of interruptions of the grid. For these purpose, only those interruptions caused by zero voltage, lasting more than a minute, are counted.

E.g. for Spain at 31-12-2012 the Energy Not Supplied was: 113 MWh

The Average Interruption Time, AIT (minutes)

It is defined as the relation of the Energy not Supplied and the average power of the system.

E.g. for Spain at 2012the Average Interruption Time was: 0.28 minutes

4.1.3 Consumption and demand

Annual consumption (GWh)

It refers to the quantity of electricity consumed in a country for a specific year i.e. the electricity that arrives to the consumers.

E.g. for Spain at for 2012 the annual consumption was: 251,710 GWh

Annual consumption (KWh/hab)

It refers to the quantity of electricity consumed in a country for a specific year i.e. the electricity that arrives to the consumers divided by the number of habitants.

E.g. for Spain at 2012the annual consumption per capita was: 5376.35KWh/hab

Instantaneous peak power demand and minimum power demand (GW)

They are respectively defined as the highest and lowest value of the power load demanded in a year.

E.g. for Spain at 31-12-2012 the Instantaneous peak power demand was: 43.53 GW

International exchanges (GWh)

It is defined as the quantity of electricity interchanged between countries through the international interconnections.

E.g. for Spain at 2012 the international electricity exchanges with its neighbours were the following:

NET BALANCE	**11,187 GWh**
IMPORTS	-6,272 GWh
EXPORTS	17,459 GWh

Figure 6: International exchanges Spain 2012. Source: REE (13), own development.

The interconectiion between different countries ensure a better service for the consumer improving the quality and providing stability to the system. The net balance is the result of substracting the imports to the exports, so if a country exports electricity, its balance will be positive.

4.1.4 Market and prices

Annual price of electricity

It is the result from multiplying the average total price of electricity times the total electricity consumed in a year. The result, although is not fully accurate, gives an idea of the total expenditure of electricity in a country

Daily market prices

Electricity transactions for the following day through the presentation of electricity sale and purchase bids by market participants.

E.g. for Spain at 2012 the average daily market price was: 42.10 € MWh

Intraday market price

Agents may once again buy and sell electricity on the intraday market; that is, at different trading sessions some hours earlier than real time.

E.g. for Spain at 2012 the average intraday market price was: 51.40 €/MWh

Chapter 5.- ATLAS DEVELOPMENT

5.1 Source of information

To compile all the information required to develop the indicators in this chapter, the next table resumes all the main sources of information for the development of most of them.

SPAIN	
REE	Spanish Electricity System annual and monthly reports
OMIE	Annual price report
CNMC	Boletín indicadores eléctricos
FRANCE	
RTE	Annual Electricity Report
	Generation adequacy report
CRE	Functioning of the wholesale electricity, CO2 and natural gas markets
THE UNITED KINGDOM	
National Statistics GOV.UK	DUKES Chapter 5: Electricity Department for Business, Energy & Industrial Strategy
OFGEM	Electricity wholesale market
ieefa	Electricity-Grid-Transition-in-the-U.K
GERMANY	
bundesnetzagentur	Monitoring report annual
ise.fraunhofer	Power generation in Germany
	Electricity production in Germany
EUROPE	
Entsoe	Electricity in Europe
iea	KEY WORLD ENERGY STATISTICS
Eurostat	Historic statistic
ACER	Market monitoring report
CIGRE	The Electric Power System

Figure 7 Main source of information

	TSO	MARKET REGULATOR	MARKET OPERATOR
SPAIN	REE	CNMC	OMIE
GERMANY	TenneT, 50Hertz Amprion TransnetBW	Bundesnetzagentur	EPEX
FRANCE	RTE	CRE	EPEX
UK	National grid	OFGEM	EPEX
EUROPE ASSOCIATION	ENTSOE	ACER	

Figure 8: Important countries organisms

5.2 Electrical indicators in Spain

Current legislation and regulation in Spain

Spain's situation allows the creation of the Iberian Electricity Market (MIBEL), between Portugal and Spain that is aimed at constructing a regional electricity market.

At the appendix (at the end of the document) it can be consulted all the laws concerned to the electric sector, however it is important to mention Ley 24/2013, de 26 de diciembre, del Sector Eléctrico (BOE 27/12/2013)

Main agents in the electric system

Spain situation allows to create the Iberian Electricity Market (MIBEL), between Portugal and Spain that is aimed at constructing a regional electricity market.

With the MIBEL, it becomes possible for any consumer in the Iberian zone to acquire electrical energy under a free competition regime, from any producer or retailer that acts in Portugal or Spain as previously explained in "electrical system in Spain".

→ **Iberian Market Operator**

- OMIP is the Iberian exchanger of electricity derivatives, which ensures the management of the market.
- OMIE as the electricity market operator manages the entirety of the markets (daily and intraday) for the entire Iberian Peninsula
- OMIClear is in charge of the functions of Clearing House and Central Counterpart of the operations carried out in the market.

Figure 9: Corporative structure of Iberian market operators. Source: OMIE (15).

→ **Regulatory bodies**

- The Ministry of Energy, Tourism and the Digital Agenda (MINETAD)
- CNMC is in charge to supervise and control the correct operation of the electricity markets.

→ **Generation**

Electricity generation and supply in Spain is dominated by the following energy companies, notable for their large market share: Endesa, Iberdrola, Gas Natural Fenosa, EDP/Hidrocantábrico and Viesgo.

→ **Transmission and distribution organisms**

REE is the transmission system operator (TSO), its mission is to guarantee the safety of the installations, the transmission of electricity from the generators to the distribution operators and their availability according to the needs of the Spanish electrical system ensuring the supply of electricity

The distribution system operator (DSO) companies have the mission of distributing, building, maintaining and operating distribution facilities to place energy at the points of consumption. In Spain the main DSO companies are: Endesa distribución, Iberdrola distribución, Gas Natural Fenosa distribución, Viesgo distribución (previously named e•on) and Hidrocantábrico distribución.

Electrical indicators

This section presents and analyses the data obtained for Spain from the period 2012-2016 (area excluding the autonomous cities of Ceuta, Melilla and the Spanish Islands) for the electric indicators. Therefore the next items, as it was explained in detailed in chapter “electrical indicators”, are analysed:

5.2.1 Generation

→ **Installed power capacity**

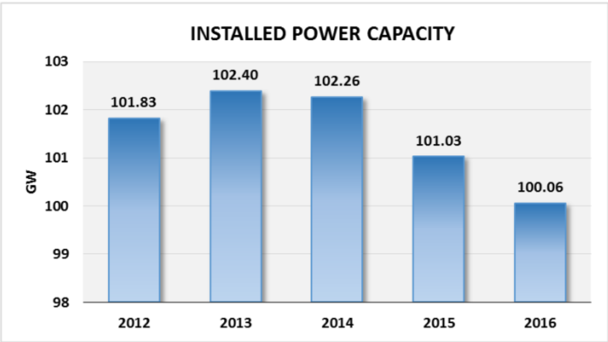


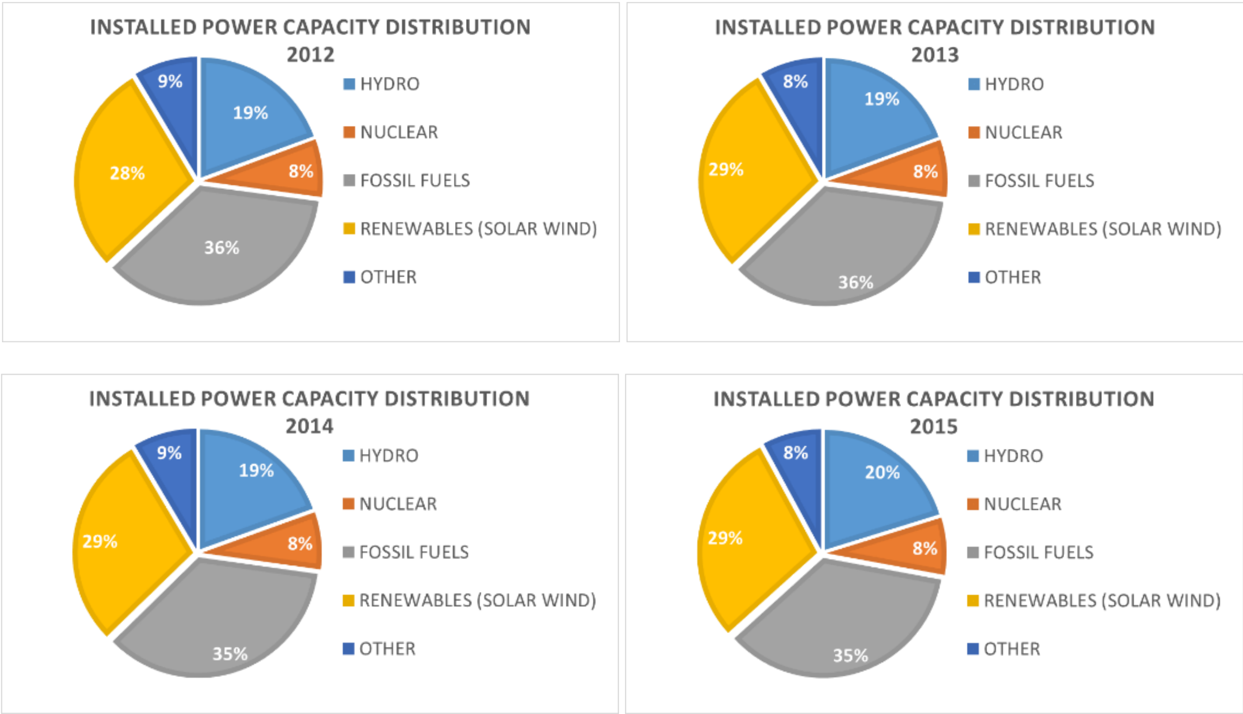
Figure 10 Installed power capacity Spain. Source: REE (6), own development.

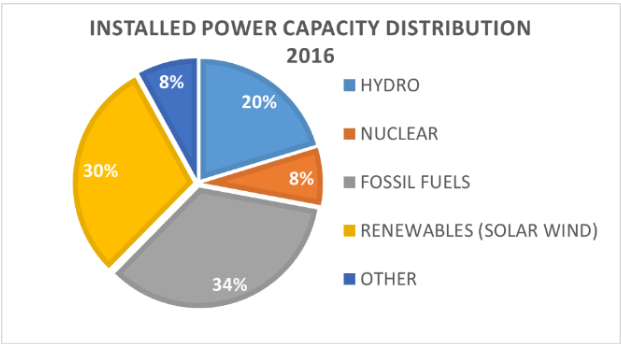
The above figure shows the installed power capacity in Spain during the years 2012 to 2016. The installed power capacity of the observed years ranges from 101.828 to 100.059 GW, presenting an increase in 2013 and 2014 with respect to 2012. Nevertheless, the trend is very stable and the variations in the last years accounts for less than a 3%.

The amount is overall above the maximum power demand by 250% and even though it is expected that the expressed maximum capacity of 100.06 GW is never available at the same time, there is still room in the country for the demand to increase before it meets the total capacity.

→ **Installed power capacity distribution by technology**

Thus, the analysis of the installed power capacity continues with the study of the distribution by type of technology from 2012 to 2016 in the Spanish peninsula area. (See graphs below)





TECHNOLOGY	GW
HYDRO	20.35
NUCLEAR	7.57
FOSSIL FUELS	34.48
RENEWABLES (SOLAR WIND)	29.63
OTHER	8.02
TOTAL	**100.06**

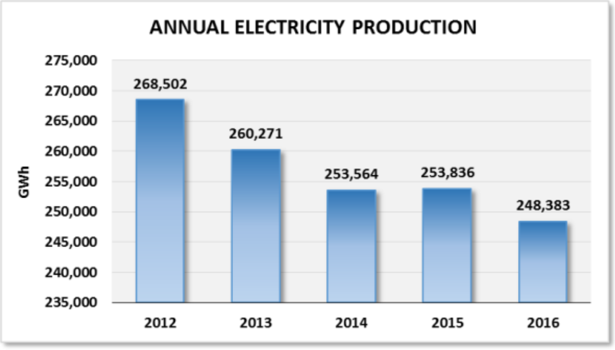
Figure 11: Installed power capacity distribution Spain. Source: REE (6), own development.

It is shown how the different technologies keep (more or less) their shares in the total installed capacity.

In fact, nuclear power is the only technology that really maintains its maximum power capacity exactly the same. This is due the fact that there have not been constructed new nuclear power plants in the period, which makes its capacity with respect to the total to remain constant.

Also, the fossil fuels sector presents a small loss in its share, which is captured by the renewable energies, these are hydro, wind and solar. This trend confirms the estimation that for the next upcoming years there will be an increment in the renewable technology to the detriment of the fossil fuels. In fact, the hydro is close to its maximum physical capacity in the Peninsula and today nuclear plants are in their last years of operational life.

→ **Annual electricity production (absolute values)**



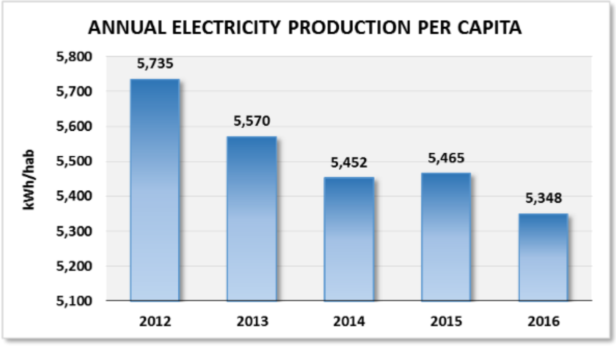


Figure 12 Annual electricity production Spain. Source: REE (6), own development.

The graphs above shows the evolution of the annual electrity production and the annual electrity production per capita for the spanish area system measured in GWh and KWh/hab respectively.

In first graph it can be observed a falling trend from 2012 to 2016. The reasons why there is a drop in the annual production are diverse, but the main ones are those related to the economic crisis, the renewable production and with the improvement in the effiency of the electricity consumption and therefore the resulting “savings”.

Since the population variation is very small, the drop in the production per capita is due to a reduction of the annual electricy production that has happened in the last years.

As we have seen, the demand is not the same for every year but it also changes amongst months because of the different weather conditions among other facts. (See Graph below).

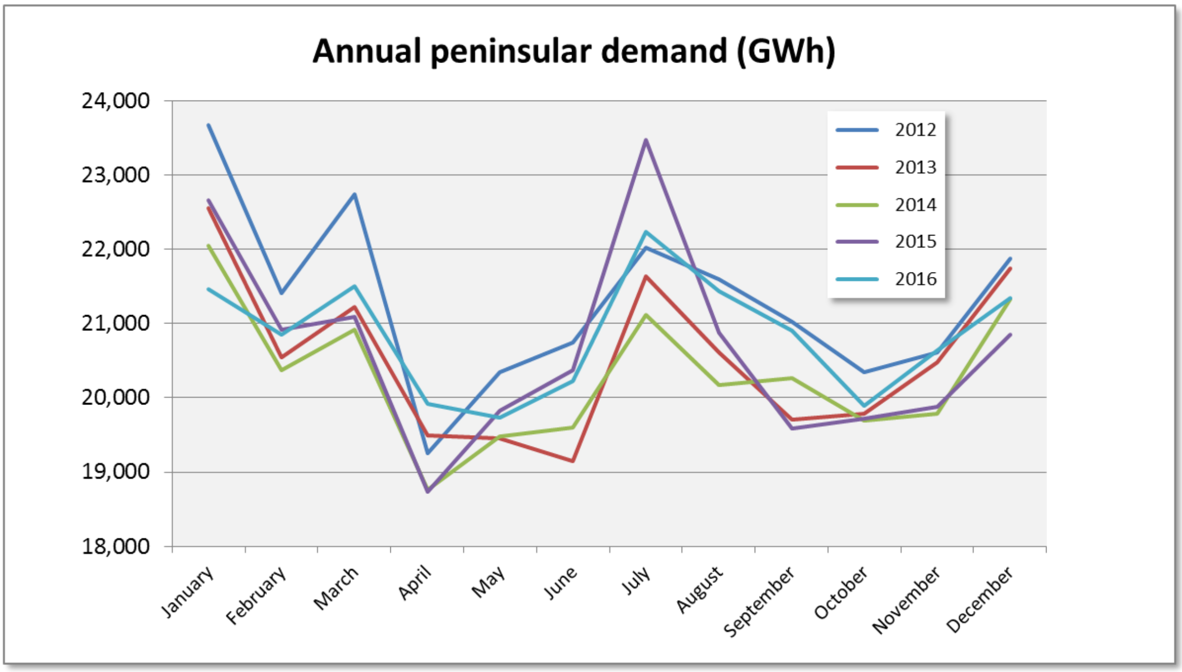
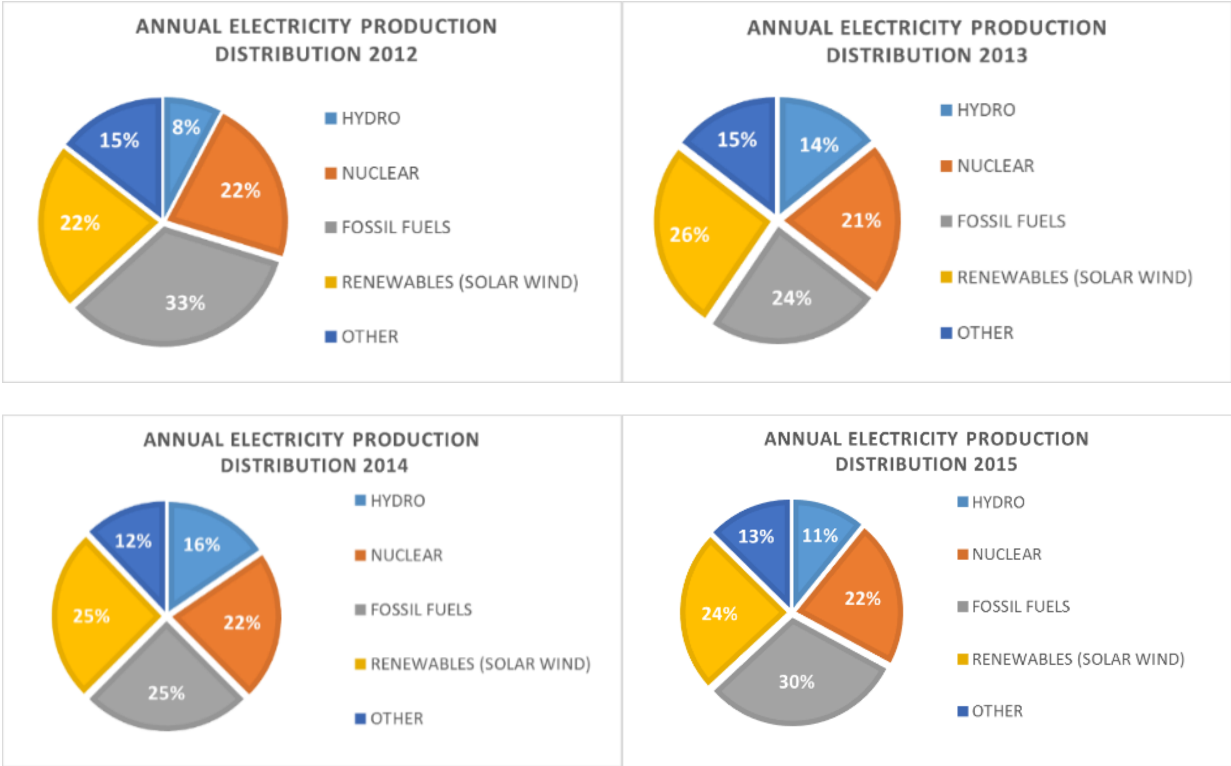
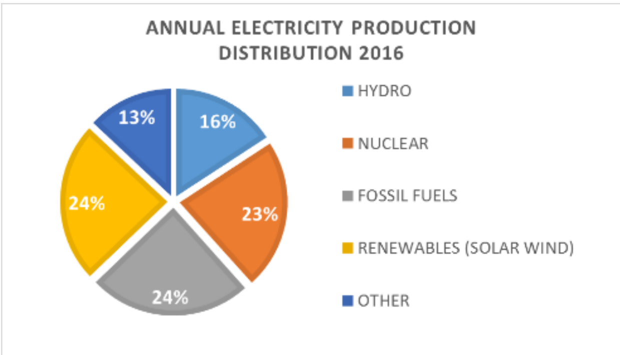


Figure 13 Monthly electricity production Spain. Source: CNMC (16), own development.

→ Annual electricity production distribution by technology (%)





TECHNOLOGY	GWh
HYDRO	39168
NUCLEAR	56099
FOSSIL FUELS	60874
RENEWABLES (SOLAR WIND)	59923
OTHER	32319
TOTAL	248383

Figure 14 Annual electricity production distribution Spain. Source: REE (6), own development.

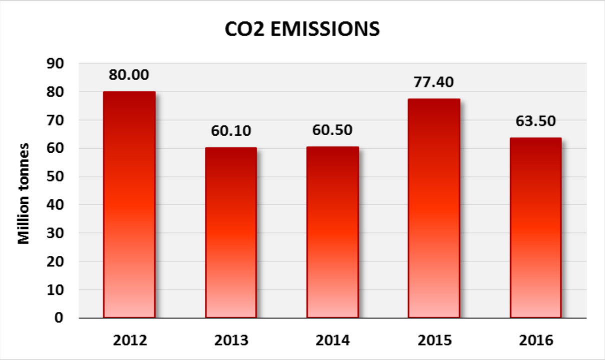
The figures above show the evolution of the distribution in the production of electricity classified by means of technology.

On the one hand, as the annual production variates very little and the nuclear electricity production due to its technical characteristics is constant, its range with respect to the total amount of the production is nearly constant.

On the other hand, those technologies that depend completely on the weather (renewables) or the markets, vary a lot depending on the year.

Keeping in mind the data from the installed capacity distribution, if it is compared to the production distribution onethey do not match. The main reasons are political decissions, the market prices and the avilability of the different ways of generating electricity. As previously pointed out, while the renewables production is not constant the nuclear is.

→ CO2 emissions due to electricity production



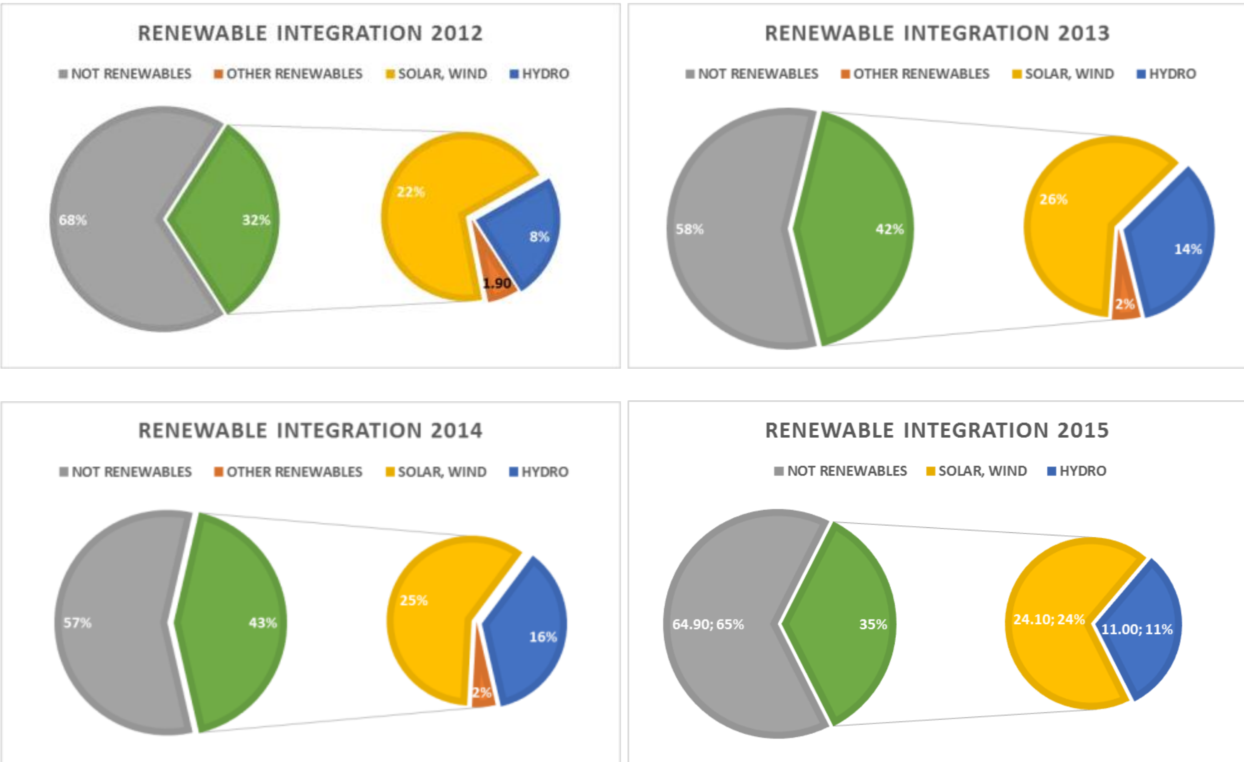
Year	Fossil fuel technology in the electricity generation (%)	CO2 emissions (million tonnes)
2012	33.4	80
2013	24.1	60.1
2014	25	60.5
2015	30.4	77.4
2016	24.5	63.5
Main fossil fuel technologies in the electricity generation		**CO2 emissions (tCO2/MWh)**
COAL		1.09
COMBINED CYCLE		0.41

Figure 15: CO2 emissions Spain Source: REE (6), own development.

The figure above shows how CO2 emissions from electricity production have changed from 2012 to 2016. Looking at this graph together with the distribution in the energy generated by each technology (figure 14) it can be observed that it is highly related to the fossil fuels source of electricity (coal and gas natural from combined cycle mainly), being those technologies the main CO2 emission.

→ Integration of renewables (%)

The next charts are shown the evolution in the impact of renewable electricity generation from 2012 to 2016 and a more detailed vision in the renewable distribution by technology. It bears out the CO2 emissions related to the generation of renewable electricity



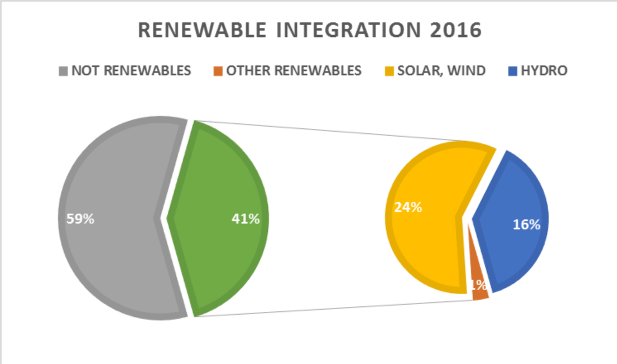


Figure 16: Renewable integration Spain 2012. Source: REE (6), own development.

5.2.2 Network. Transmission and distribution.

→ Nominal power of the distribution lines

The nominal power used for the distribution lines in Spain can be classified depending of its voltage level as follows (17):

High voltage: 132/110/66/50/45 kV

Medium voltage: 33/30/25/20/15/13.2/11/10/6/3/1 kV

Low voltage: 0.4 kV

→ Length of the distribution system

The distribution system length could be divided into high, medium and low voltage, as it was previously described, but also between aerial and grounded depending on its position. In terms of security the grounded lines are near to population.

	Aerial (km)	Grounded (km)	TOTAL
HIGH VOLTAGE	48,533	2,642	**51,175**
MEDIUM VOLTAGE	183,251	83,465	**266,716**
LOW VOLTAGE	237,686	193,317	**431,003**
TOTAL	**469,470**	**279,424**	**748,893**

Figure 17: Length of the distribution system Spain. Source: Unesa (17), own development.

→ Total losses in the distribution system

Total losses produced in the distribution lines were 21.52 TWh in the year 2016. The sum of the power generated plus the electricity imported during the year 2016 corresponds to 256 TWh, which means that 8.4% of the electricity was lost in the distribution grid.

→ **Length of the transmission system**

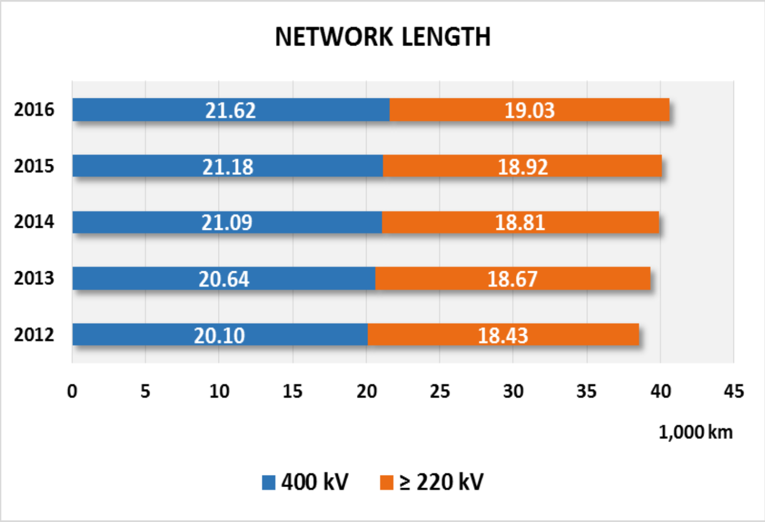
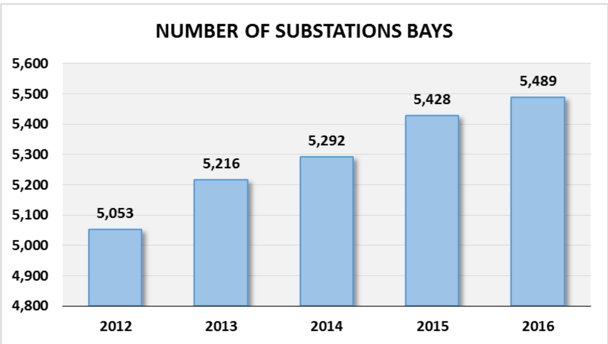


Figure 18: Length of the transmission system Spain. Source: REE (6), own development.

The represented data on the network wealth (graph above) shows the length of the grid with a voltage level over or equal to 220 kV (i.e. transmission network). The km of circuit are subdivided in 400kV and higher or equal to 220 kV. As it is shown, there is a slightly increment in the length of the grid both in 400kV and in 220kV for every year, with the aim to achieve a more sophisticated and bigger network system. Due to the localization of the lines, mainly at the countryside, most of the lines are open air lines while only less than 600 km are grounded. REE publishes annually a detailed map of the network system[1].

→ **Number of substations bays and investment.**



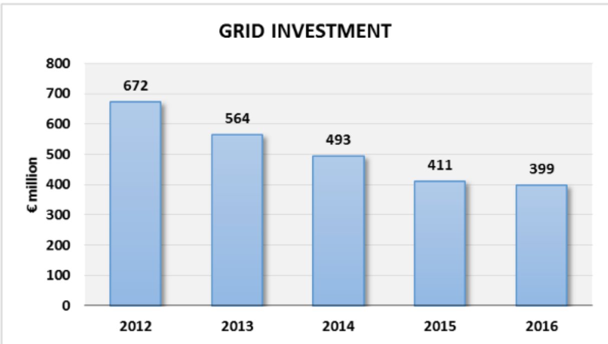


Figure 19: Number of substation bays and grid investment Spain. Source: REE (6), own development.

The figures above show the evolution in the number of substation bays and the investment executed from the year 2012 to 2016. As it occurs with the grid length, the number of substations bays is growing every year. This is aimed at improving the quality and the size of the system.

With respect to the investment in the electrical grid, there is a drop down to 411 million €, which accounts for a 66% of the amount invested in 2012 mainly due to the crisis and deficit of the system.

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1 http://www.ree.es/sites/default/files/01_ACTIVIDADES/Documentos/Mapas-de-red/mapa_transporte_iberico_2017.pdf

→ Energy not supplied and average interruption time (AIT)

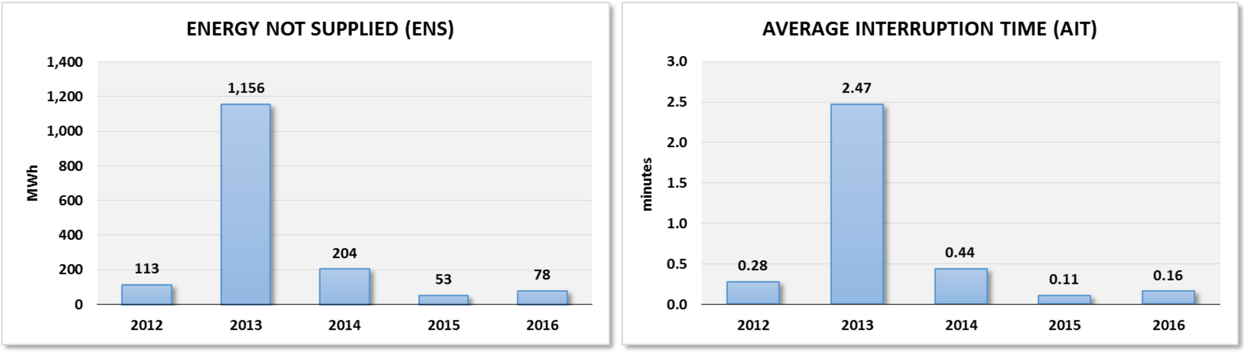

Figure 20: ENS and AIT Spain. Source: REE (6), own development.

The figures above show the evolution of the energy not supplied by the system and the average interruption time[2].

The causes of the nonsupply are explained by technical problems in the grid and tend to be more frequent in rural areas. As it occurs with the grid availability, the variation in the different years is the result of isolated incidents. In 2013 two incidents in large consumers directly connected to the transmission network that accounted for almost 86% of the total ENS for that year (18).

If the average interruption time is observed, 2013 shows the highest value, according to the observed data on energy not supplied since there is a causality relationship between them.

→ Grid availability transmission

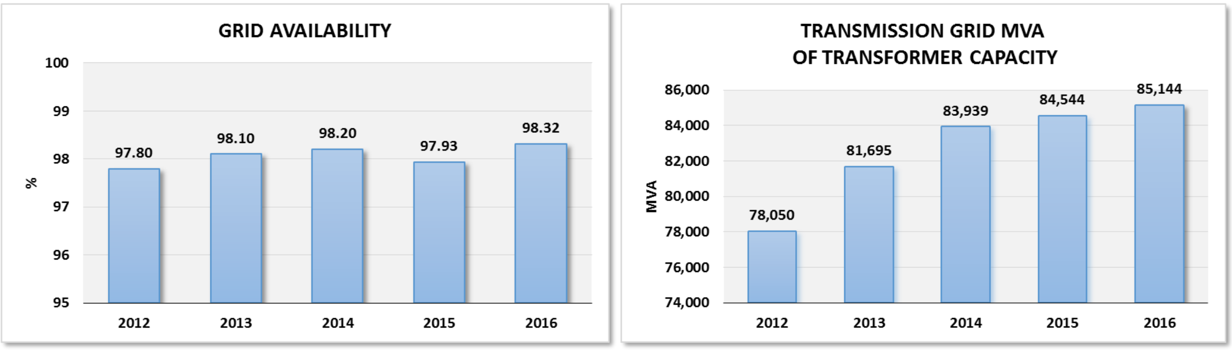

Figure 21: Grid availability and transf. capacity Spain. Source: REE (6), own development.

The figures above show the grid availability and the transformer grid MVA of transformer capacity along the years.

The grid availability, measured in percentage of time, is near 100% for the four years. This is a very relevant quality of the Spanish electricity system, and the narrow variation along the different years is due to isolated cases.

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[2] The values are below the reference value of 15 minutes stablished in the art. 26.2 Real Decreto 1955/2000 de 1 de diciembre

→ **Expected system cost**

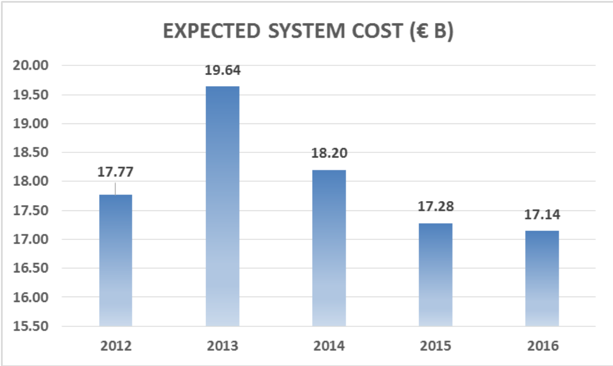


Figure 22: Expected system cost Spain. Source: CNMC (16), own development

The above figure presents the variation in the expected system cost between the years 2012 to 2016.

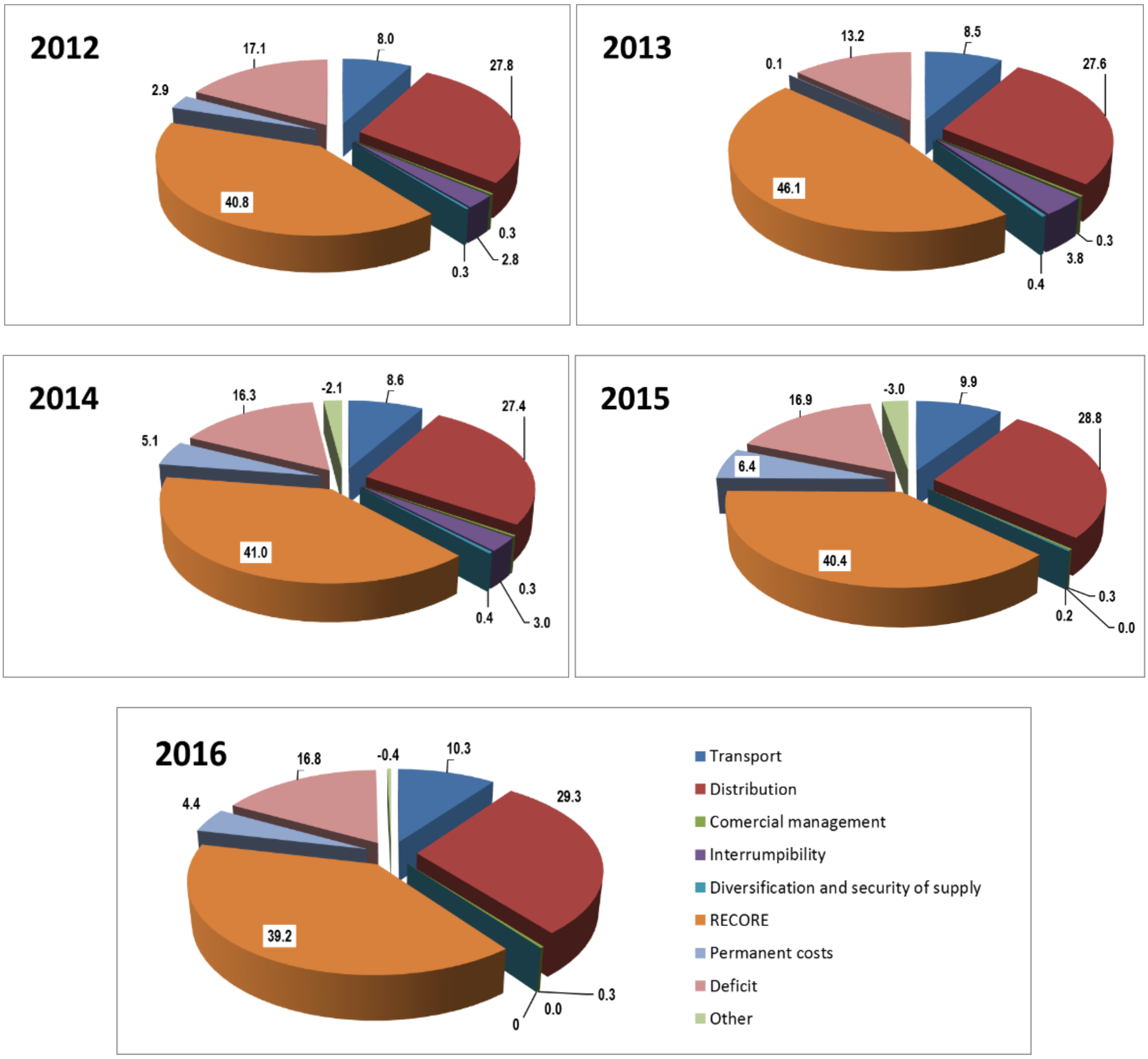


Figure 23: Expected system cost distribution Spain. Source: CNMC (16), own development

The figures above divide the expenses between the different main costs. The main costs every year are the ones relative to the RECORE (due to its name in Spanish, Régimen Retributivo Específico), the distribution and the deficit. The RECORE refers to the renewables' aids and retributions given in the last years from political decisions to promote the renewable generation.

5.2.3 Consumption and demand

→ Annual consumption

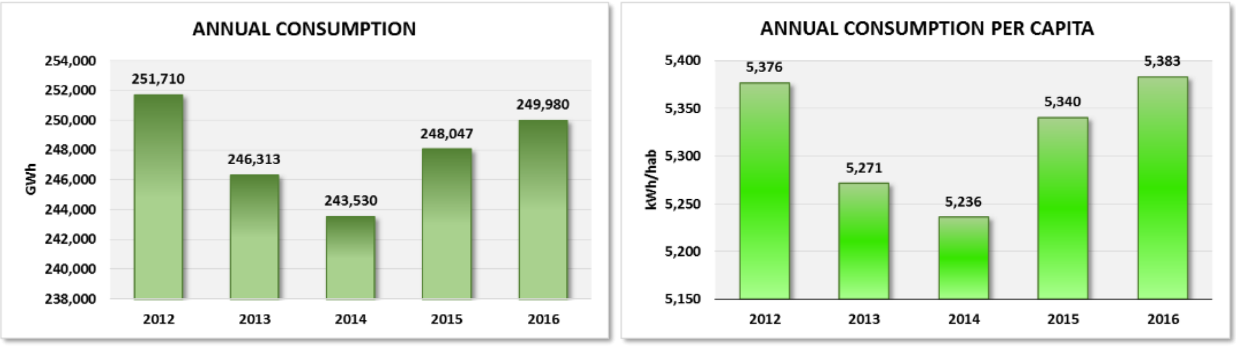


Figure 24: Annual consumption Spain. Source: REE (6), own development

Above graphs show the evolution of the annual electric consumption and the evolution of the annual electrity consumption per capita in Spain between the years 2012 to 2016.

The graph shows that, despite the consumption has decreased from 2012 to 2014 due to the crisis and the market amongst others, during the year 2015 to 2016 the amount of GWh consumed recovers its previous value.

This graph keeps a close relationship with the one of annual production of electricity because the production of electricity depends almost completely on the electricity consumed, and the difference between both of them is due to the losses in the network, which are bigger in the distribution system. (Also the illegal interconnections into the grid are included).

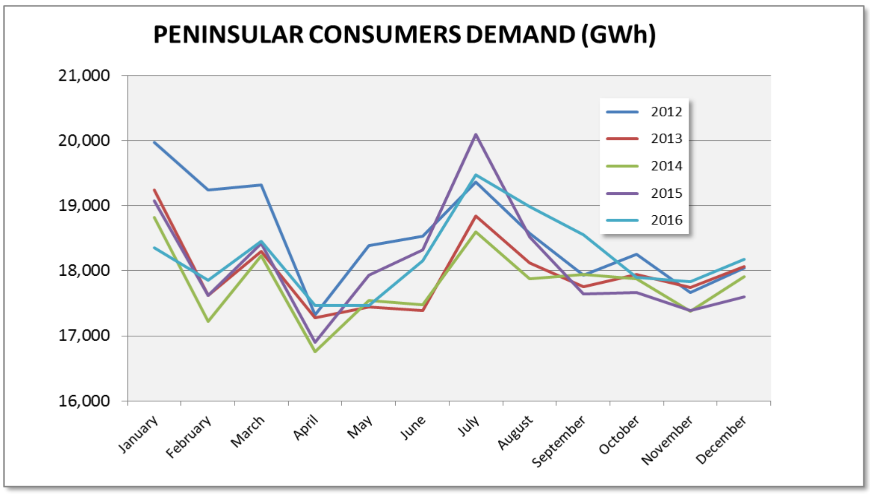


Figure 25: Monthly consumption Spain. Source: CNMC (16), own development

Due to the fact that population variations are very small, changes in the graph are related to changes in the annual electricy consumption as it follows the same variation distribution with softer variations.

As it occurs with the production of electricity, consumption changes along the different years but also within each of them because of weather conditions and other facts. (See graph above)

→ Instantaneous peak power demand and minimum power demand

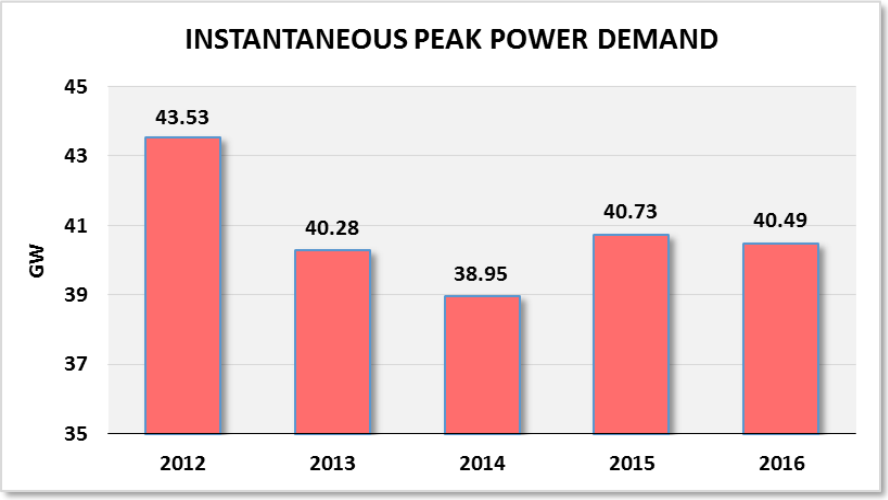


Figure 26: Instantaneous peak power demand Spain. Source: REE (6), own development

Above graph shows the maximum instantaneous power demand in Spain during the period 2012 to 2016. It illustrates a decreasing trend until 2015 while it reaches the minimum amount in 2014, which may indicate that the level prior to the crisis could be reached again. The maximum level corresponds to the year 2007 when the demanded power reached 45450MW (at 12/17/2007 18:53).

→ International exchanges of electricity

Spain is geographically isolated, which means that it can only exchange electricity with a very few countries. Spain historically buys electricity to France and sells it to Portugal, Morocoo and Andorra. Graph below shows the different points of interconection with other countries.

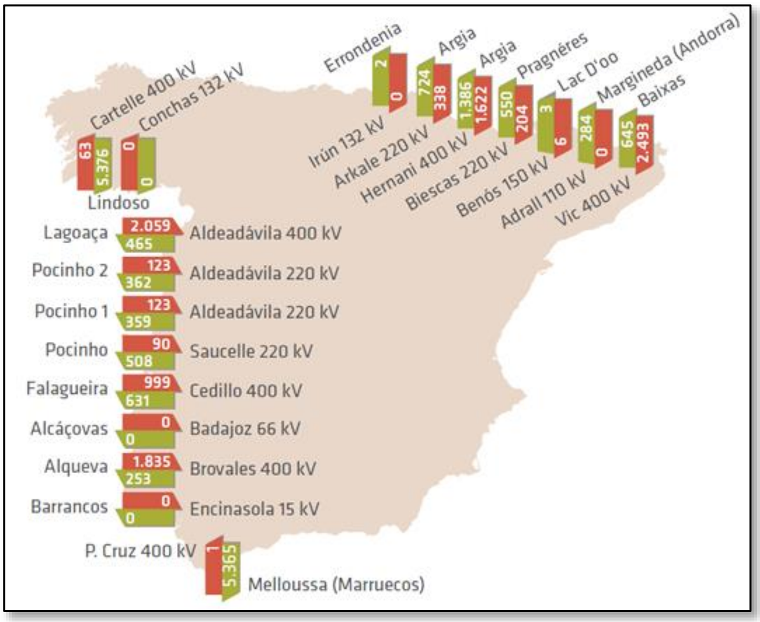


Figure 27: Interconnexions of Spain. Source: REE

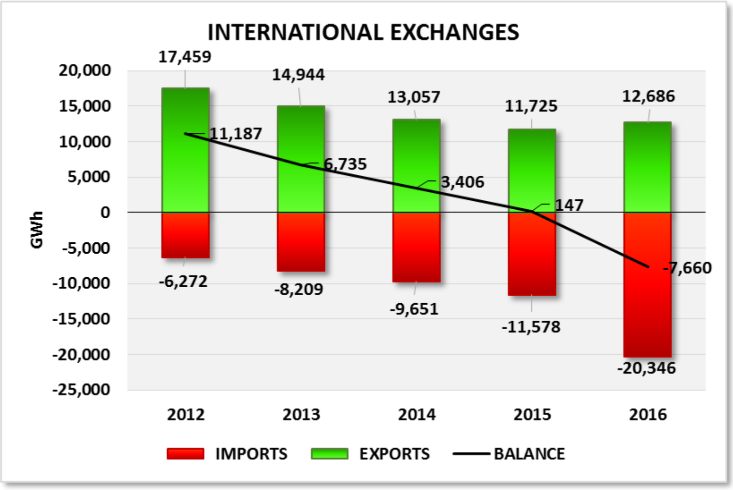


Figure 28 International exchanges Spain. Source: REE (6), own development

The next figure shows the evolution of imports, exports and the net balance of the international exchanges from 2012 to 2015. The data shows how imports as wellas exports have decreased during these years from an initial balance of 11.9 to 0.15 GWh.

	2012	2013	2014	2015	2016
NET EXCHANGES (GWh)	11,187	6,735	3,406	147	-7,660

Figure 29: international exchanges Spain. Source: REE (6), own development

5.2.4 Market

OMIE manages the wholesale electricity market (referred to as cash or "spot") on the Iberian Peninsula. Like any other, the electricity market caters for the trading of electricity between agents (producers, consumers, retailers, etc.) at a price that is known, transparent and accessible.

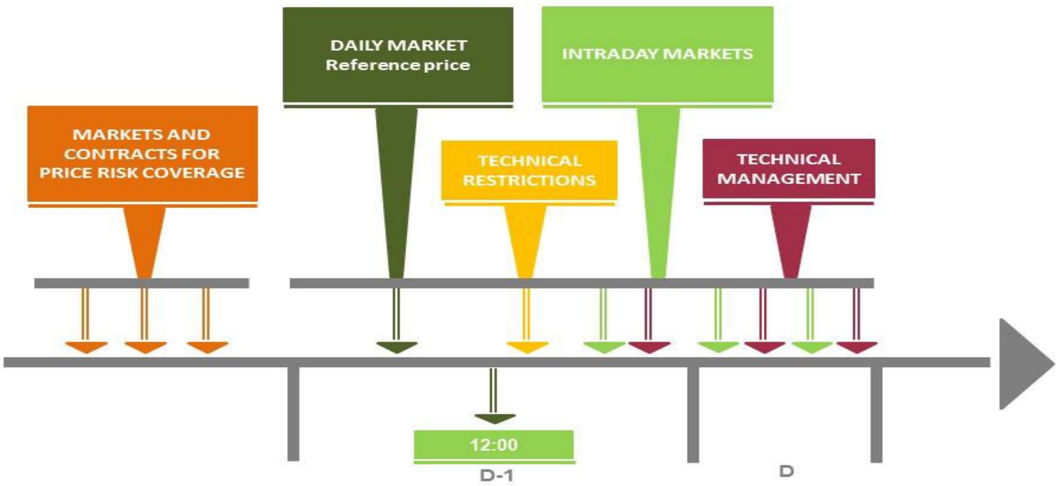


Figure 30 Time sequence for markets and processes in MIBEL. Source: Omel (19)

→ The daily market

The purpose of the daily market, as an integral part of electricity power production market, is to handle electricity transactions for the following day through the presentation of electricity sale and purchase bids by market participants

→ The intraday market

After the daily market, agents may once again buy and sell electricity on the intraday market; that is, at different trading sessions some hours earlier than real time. There are six trading sessions based on auctions such as those described for the daily market, where the volume of energy and each hourly price are determined by the point where supply and demand meet.

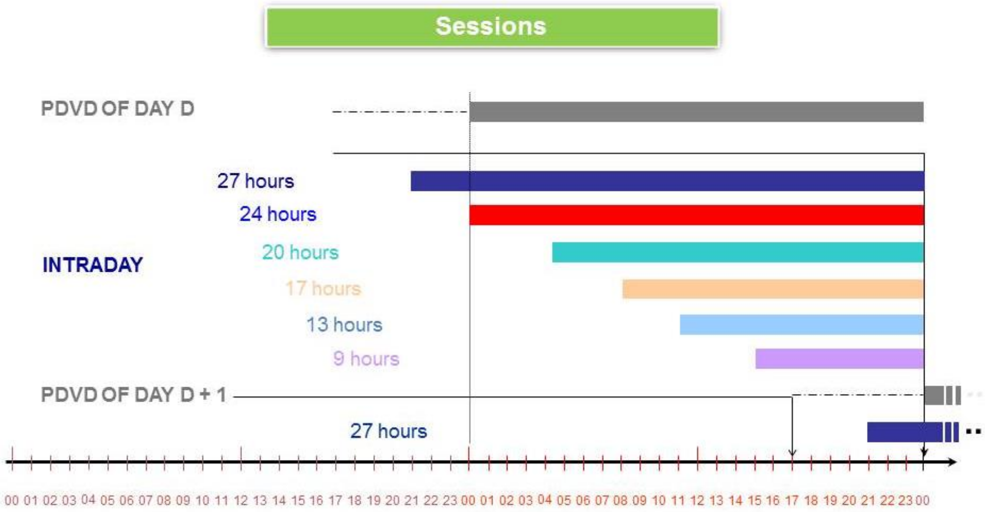


Figure 31 Intraday market in MIBEL. Time horizon for the six sessions. Source: Omel (19)

In the appendix there are all the tables referred to the different tariffs with and without discrimination and other interesting information as it could be its size or number of consumers.

Next graph is an orientalise chart of the distribution of the energy consumed by the different tariff groups.

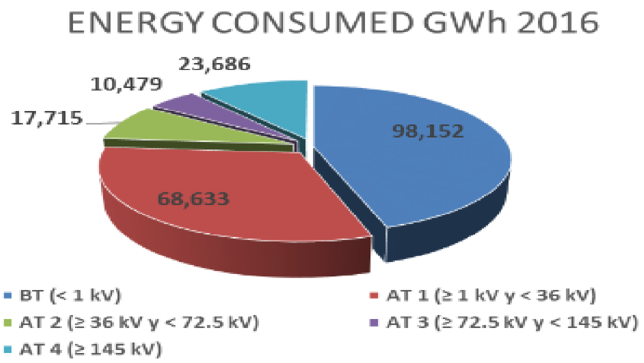


Figure 32: Monthly consumption Spain. Source: CNMC (16), own development

→ Energy values and contracting on the MIBEL

Next table collects the energy values and the contracting prices at the MIBEL in daily and intraday markets (monthly).

	Daily Market		Intraday Market		Total	
	Energy GWh	Contracting kEUR	Energy GWh	Contracting kEUR	Energy GWh	Contracting kEUR
Jan	20,520	777,734	2,885	111,126	23,405	888,860
Feb	20,682	576,794	2,642	75,617	23,324	652,411
Mar	20,020	566,024	2,665	77,490	22,685	643,514
Apr	18,410	449,988	2,739	69,043	21,149	519,031
May	18,213	478,958	2,887	78,153	21,100	557,111
Jun	18,180	716,579	2,582	101,284	20,762	817,863
Jul	20,199	835,092	2,600	107,512	22,799	942,604
Aug	19,636	823,364	2,448	101,426	22,084	924,790
Sep	19,337	859,814	2,476	109,656	21,813	969,470
Oct	19,434	1,054,251	3,017	164,658	22,451	1,218,909
Nov	21,080	1,219,695	2,802	163,341	23,882	1,383,036
Dec	21,815	1,354,877	2,474	154,695	24,289	1,509,572
Year	**237,526**	**9,713,170**	**32,216**	**1,314,002**	**269,742**	**11,027,172**

Figure 33: Energy values and contracting on the MIBEL. Source: Omel (20)

→ Average monthly price of the Daily Market (Spanish side)

Next table present the monthly pice of the daily market for the spanish side during years 2015 and 2016 and the following table the evolution in th historical annual data.

	Average Monthly Price (€/MWh)		Energy Purchased (GWh)	
	2016	2015	**2016**	2015
Jan	36.53	51.60	15,561	15,445
Feb	27.50	42.57	16,003	13,966
Mar	27.80	43.13	15,291	13,743
Apr	24.11	45.34	13,653	12,815
May	25.77	45.12	13,981	14,107
Jun	38.90	54.73	14,325	15,172
Jul	40.53	59.55	15,979	16,952
Aug	41.16	55.59	15,669	14,892
Sep	43.59	51.88	15,382	13,667
Oct	52.83	49.90	14,719	14,410
Nov	56.13	51.20	16,390	15,041
Dec	60.49	52.61	17,018	15,759
Year	39.67	50.32	183,970	175,968

Figure 34: average monthly price of the daily market. Source: Omel (20)

SPAIN	**2012**	**2013**	**2014**	**2015**	**2016**
PRICE €/MWh	47.20	44.30	42.10	50.32	39.70

Figure 35 Evolution of the middle price of the daily market Source: Omel (20) own development

→ Interesting Spanish market data

In the next figure there are interesting data related with the market prices in Spain during the year 2016.

Prices	Spain	
	€/MWh	Date
Peak Hourly	75.50	1 hour (16 Dec)
Minimum Hourly	2.30	11 hours (4 days)
Maximum Price Differ.	56.63	12 January
Minimum Price Differ.	3.17	26 May
Average Daily Maximum	66.92	15 December
Average Daily Maximum	5.46	08 May
Average Montly Maximum	60.49	December
Average Mensual Minimum	24.11	April

Figure 36: Interesting market data. Source: Omel (20)

→ Average monthly prices of the intraday market

Bellow table collects the informtion of the average monthly prices of the intraday market for the years 2015 and 2016 in the spanish side.

	Average Monthly Price (€/MWh)		Energy Purchased (GWh)	
	2016	2015	2016	2015
Jan	37.68	53.51	2,500	2,646
Feb	28.34	44.23	2,320	2,598
Mar	28.86	43.90	2,341	2,641
Apr	25.13	47.24	2,382	2,231
May	26.53	45.86	2,493	2,361
Jun	38.95	55.55	2,234	1,972
Jul	41.36	60.30	2,300	2,165
Aug	41.28	55.82	2,117	2,254
Sep	44.08	51.45	2,240	2,351
Oct	53.80	50.82	2,627	2,426
Nov	58.20	53.39	2,474	2,399
Dec	62.30	54.11	2,176	2,281
Year	40.60	51.40	28,205	28,324

Figure 37 average monthly price of the intraday market. Source: Omel (20)

5.3 Electrical indicators in the European Union

In this part of the project, in order to continue with the study of certain electricity indicators, different countries of the European Union will be analysed by following the same structure as in the Spanish case. The countries which have been chosen present similar characteristics to Spain, in the sense of economics, market development and politics. These are: Germany, France, and the United Kingdom. Finally a general overview of the European Union will be presented.

5.4 Germany

Current legislation and regulation in Germany (21)

The main pieces of legislation in the energy sector in Germany are:

- Energy Industry Act (Energiewirtschaftsgesetz (EnWG))
- Renewable Energies Act (Erneuerbare-Energien-Gesetz (EEG)).

Main agents in the electric system

The main regulatory authorities that control and participate in the electric system in Germany are the following:

- Federal Network Agency (Bundesnetzagentur (BNetzA)).
- Ensure non-discriminatory grid access.
- Control grid access tariffs charged by grid operators.
- Safeguard against anti-competitive practices by grid operators.
- Monitor the implementation of the regulatory regime.
- Generally competent for electricity TSOs in Germany.
- State regulatory authorities (Landesregulierungsbehörde).
- Federal Cartel Office (Bundeskartellamt (BKartA)).
- Merger control.
- The protection of competition.
- The operation of the MTS in co-operation with the BNetzA.
- Market Transparency Authority for Electricity and Gas (Markttransparenzstelle Strom und Gas (MTS)).
- Federal Environment Agency (Umweltbundesamt (UBA)).
- The UBA is the competent authority for environmental issues. It includes the DEHSt which governs the trading of emission certificates under the Kyoto Protocol.
- German Emission Trading Authority (Deutsche Emissionshandelsstelle (DEHSt)).

Generation

The "Big Four" electricity generators: RWE, E.ON, Vattenfall or EnBW represent 76.2% of the electricity generated in Germany and around 67.6% of the total capacity installed (22).

	TWh	Market Share
RWE	125.1	32.2%
Vattenfall	83.1	21.4%
EnBW[1]	49.0	12.6%
E.ON	38.6	9.9%
CR 4		**76.2%**
Other companies		23.8%
Total net electricity generation	388.2	100%

	GW	Share
RWE	26.0	27.4%
Vattenfall	16.7	17.5%
EnBW[1]	11.9	12.6%
E.ON	9.6	10.1%
CR 4		**67.6%**
Other companies		32.4%
Total capacity	95.1	100%

Figure 38: Share of German electricity generators. Source: BNetzA (23)

<u>Transmission and distribution organisms</u>

There are currently four transmission system operators (TSOs) that form the German interconnected system. They are TenneT, 50Hertz, Amprion and TransnetBW.

Furthermore, there are also 883 German distribution system operators (DSOs) owned typically by municipalities. Although the "Big Four" have managed to acquire shares in numerous DSOs through privatisation, efforts by the municipalities in the past tend to prohibit new acquisitions by the "Big Four" in order to ensure the success of the liberalisation efforts on the transmission and generation level.

Network structure figures 2015

	TSOs	DSOs	Total
Network operators (number)	4	817	821
Total circuit length (km)	36,001	1,780,856	1,816,857
Extra high voltage	35,610	360	35,970
High voltage	391	96,267	96,658
Medium voltage	0	511,164	511,164
Low voltage	0	1,173,065	1,173,065

Figure 39: Map and network structure figures Germany. Source: BNetzA (23), psienergy (24).

<u>Electric indicators</u>

This section will present and analyse the electric indicators as calculated from the time period 2012-2015 for Germany. Thus, the items analysed will be the following:

5.4.1 Generation

→ Installed power capacity

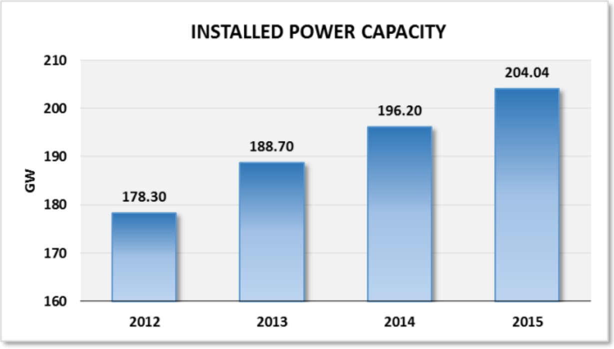
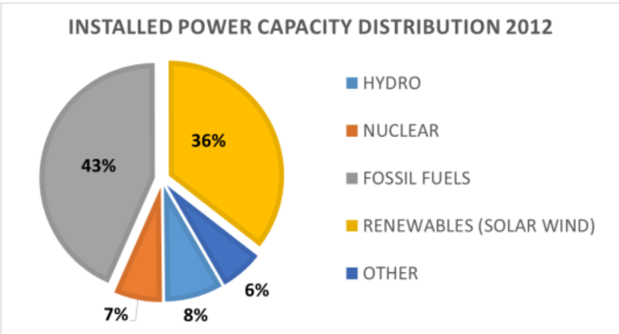
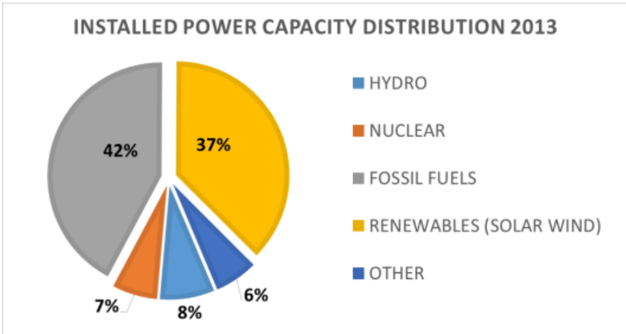


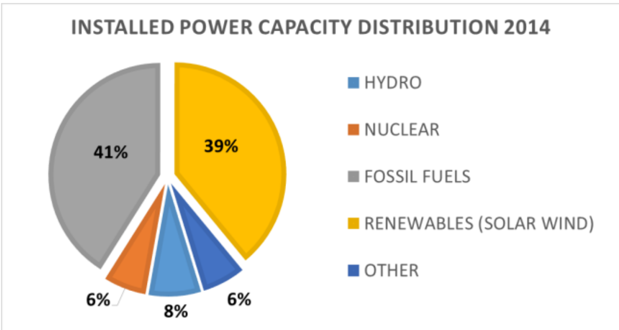
Figure 40: installed power capacity Germany. Source: BNetzA (23), own development.

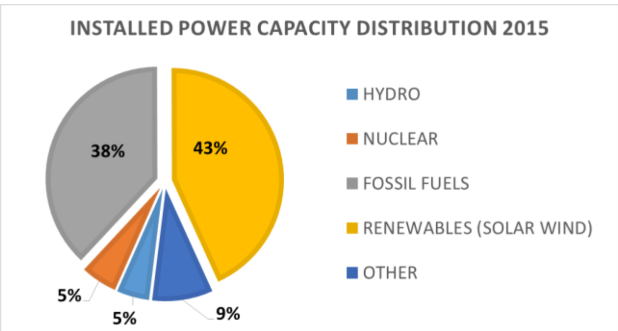
Regarding the installed power capacity of the previous graph, the data indicates that the increment year by year of the maximum capacity installed of Germany increases around a 5 % each time.

→ Installed power capacity distribution by technology









TECHNOLOGY	GW
HYDRO	9.61
NUCLEAR	10.80
FOSSIL FUELS	77.55
RENEWABLES (SOLAR WIND)	88.28
OTHER	17.81
TOTAL	204.40

Figure 41: installed power capacity distribution Germany. Source: BNetzA (23), own development.

The previous graphs express the installed power capacity distribution from 2012 to 105 in Germany, while the table refers to the amount of GW of each technology for the year 2015. The most interesting idea that can be extracted is that despite the increment in the installed capacity, the fossil fuels share is decreasing while the renewables are incrementing their presence.

→ Annual electricity production (absolute values)

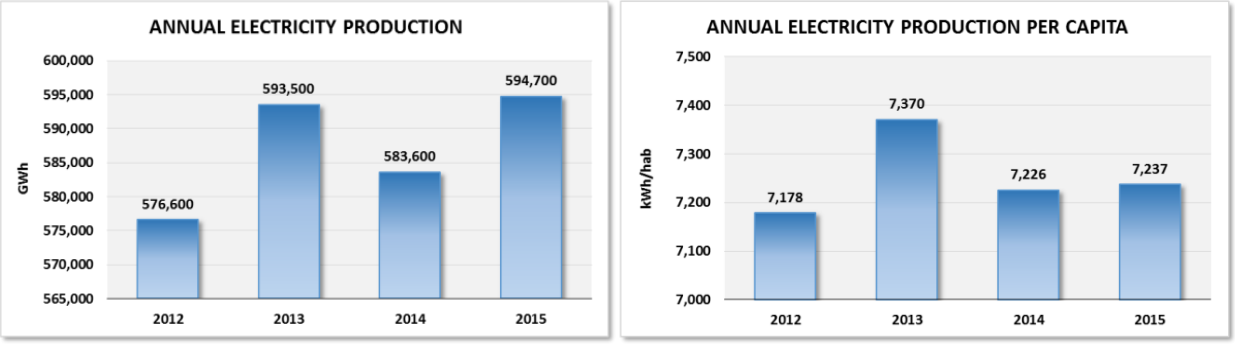
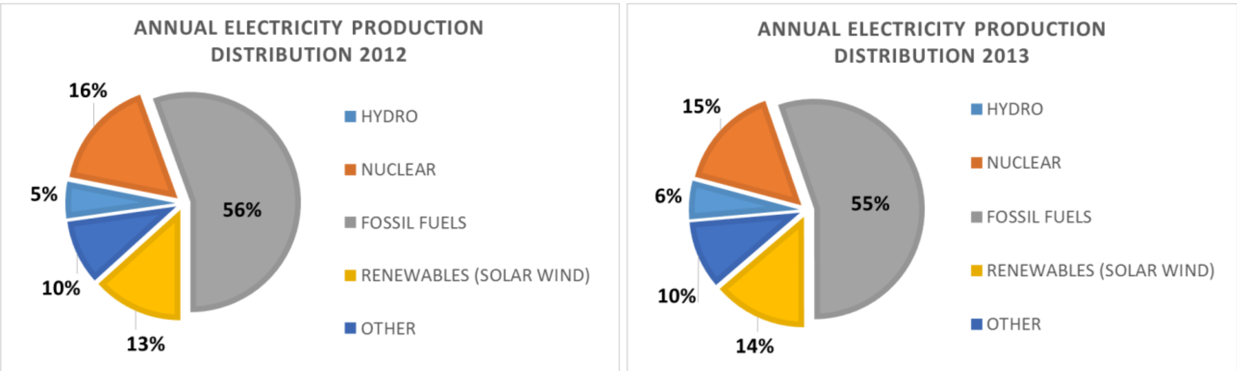
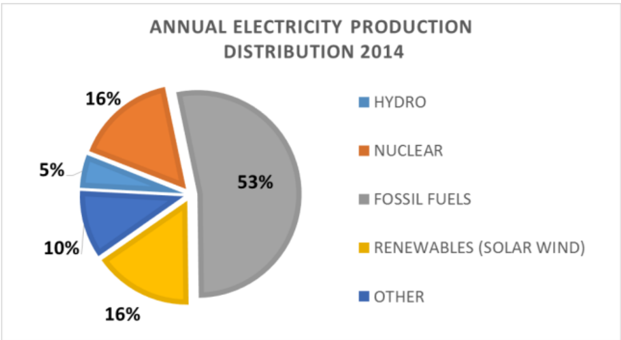


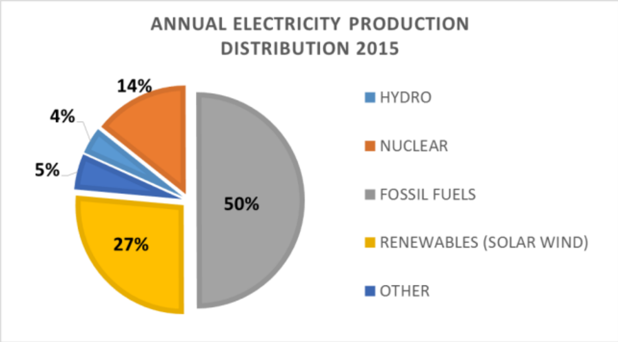
Figure 42: annual electricity production Germany. Source: BNetzA (23), own development.

The graphs above represent the evolution during the years 2012 to 2015 in Germany of the total annual electricity production and the annual electricity production per capita respectively. The annual production increases every year except in 2013 when due to the temperatures the production was bigger and don't continue the trend.

→ Annual electricity production distribution by technology (%)







TECHNOLOGY	GWh
HYDRO	23,700
NUCLEAR	85,100
FOSSIL FUELS	297,300
RENEWABLES (SOLAR WIND)	157,400
OTHER	31,200
TOTAL	594,700

Figure 43: annual electricity production distribution Germany. Source: BNetzA (23), own development.

The previous graphs show the evolution in the annual electricity production distribution for Germany for years 2012 to 2015. The table represents the total electricity generated by each technology during 2015. It shows that the weight of the fossil fuels technologies is decreasing, but however it continues being the main source of electricity accounting for half of the total annual production.

→ Real time information of the grid

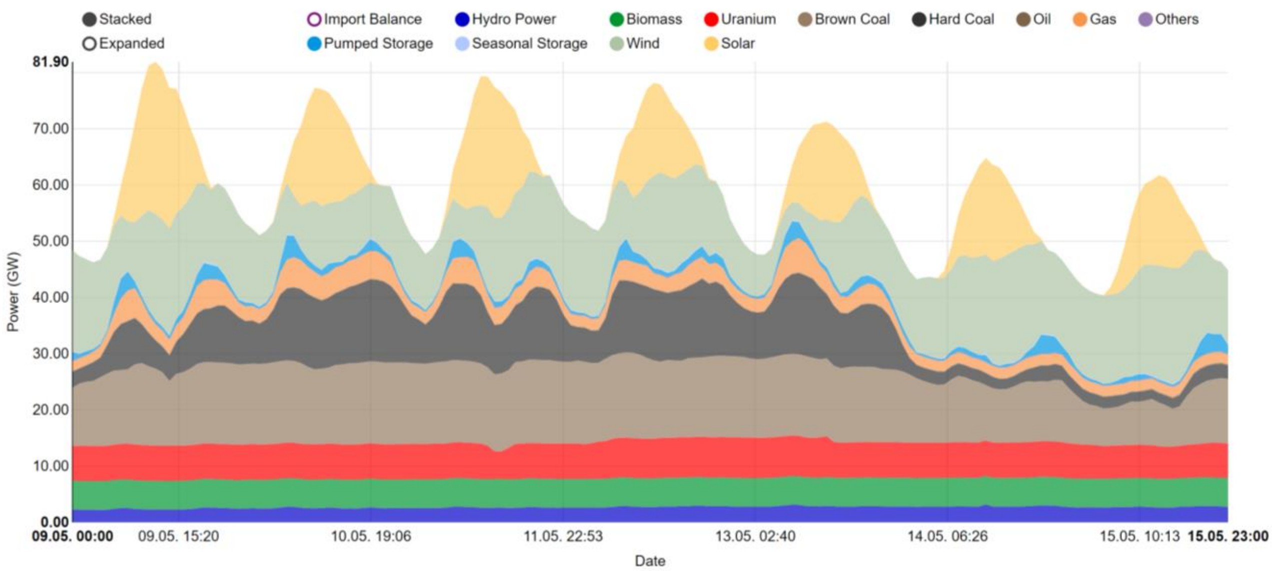


Figure 44: real time generation Germany. Source: energy-charts (25)

This image represents the electricity generation for different days in 2016 in Germany. There exists the possibility of following the status of the electricity grid online. The webpage "energy-charts.de" gives information of the demand, the different sources of electricity and other interesting data of the generation of electricity at real time as well as historical data of it.

→ CO2 emissions due to electricity production

In the year 2015 the emissions of CO2 to the atmosphere related to the electricity production reaches an amount of 301 million of tonnes (CO2). This quantity reflects the huge weight that the fossil fuels have in the generation of electricity, being these the main CO2 emitters.

→ **Renewables Integration (%)**

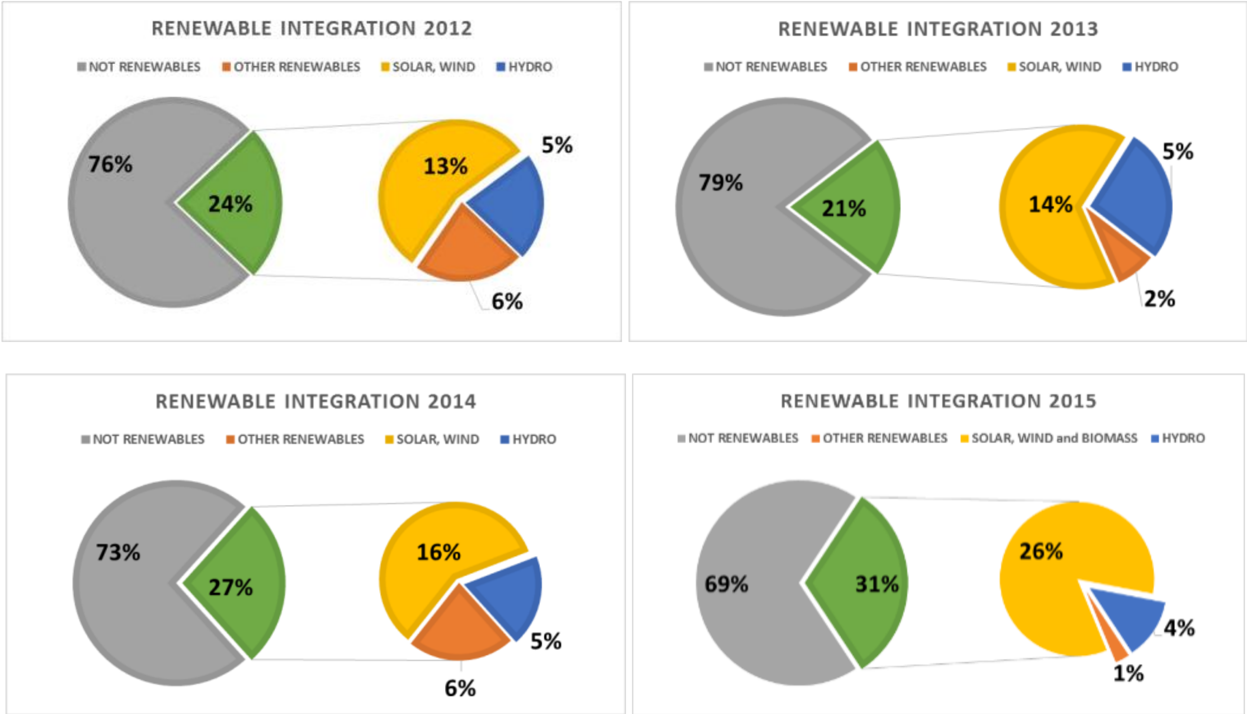


Figure 45: renewable integration Germany. Source: BNetzA (23), own development.

The previous charts represent the integration of renewables evolution during the years 2012 to 2016. There is a progressive increment in the share of renewables, and the weight of the biomass in the electricity production is remarkable, being it comparable to the hydro production.

5.4.2 Network. Transmission and distribution.

→ **Nominal power of the distribution lines and transmission grid**

GERMANY 2016		Voltage level
Transmission grid	High voltage	380 kV, 220kV
Distribution grid	High voltage	60 kV to 110 kV
	Medium voltage	6 kV to 60 kV
	Low voltage	230 V or 400 V

Figure 46: network voltage level Germany. Source: Cigre, own development.

→ **Length of the distribution and transmission system**

GERMANY 2016		Total length
Transmission grid	High voltage	36,000 km
Distribution grid	High voltage	77,000 km
	Medium voltage	479,000 km
	Low voltage	1,123 000 km

Figure 47: network length Germany. Source: Cigre (26), own development.

→ **High voltage grid map**

Figure 48: high voltage grid map Germany. Source: Cigre (26).

→ **Grid availability transmission**

The quality of the Germany transmission system still being one of the highest in the world, reaching a 0.99998 percent of time during the year 2014.

→ **Average interruption time**

The average interruption time in the electricity services was in 2015 12.70, this is, 0.42 minutes higher to the previous year, when it was 12.28 minutes. The average interruption time in 2016 was less than 12 min.

→ Investment and expenditure on network on TSO network infrastructure

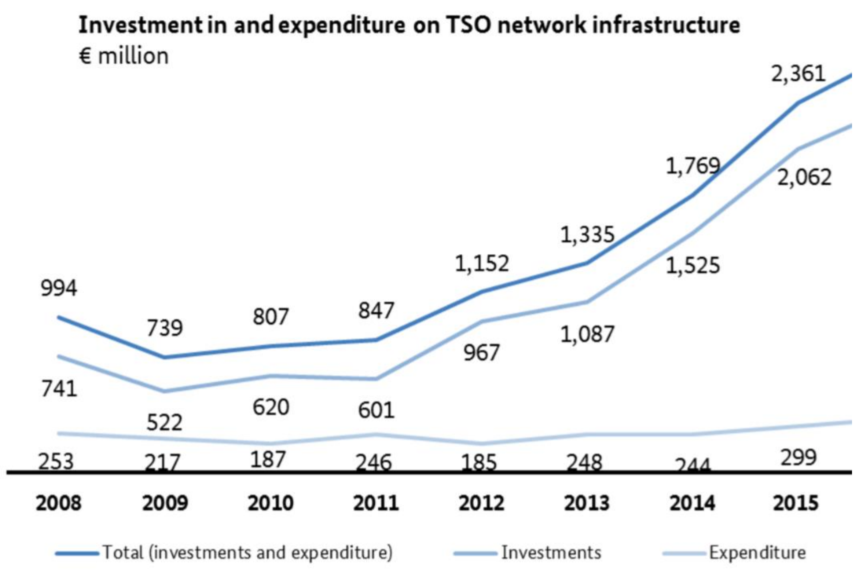


Figure 49: Investment and expenditure on network on TSO network infrastructure Germany. Source: BNetzA (23).

The chart above shows the evolution in the investment on the network infrastructure. It shows that since 2009 the expenditure has been growing year by year until it reaches an amount of 2361 million € in 2015.

→ Costs for Germany TSOs system service

The next figure presents the costs for Germany's TSO evolution since 2011 to 2015. The main costs of the system are those relative to the control reserve (primary and secondary), the curtailment quantity and finally the national and cross-border redispatch.

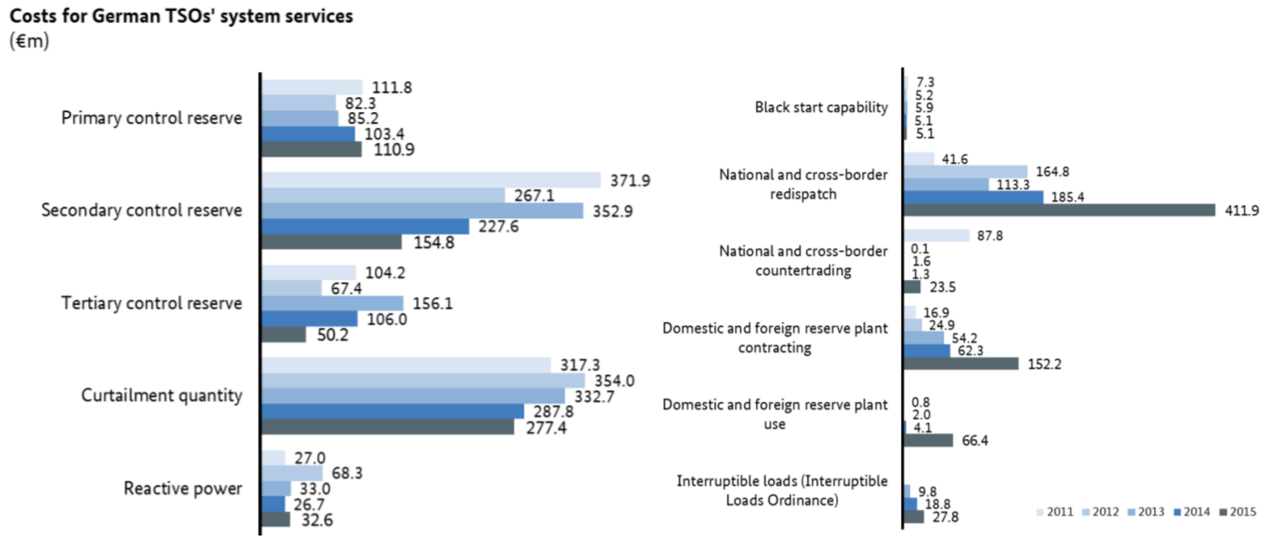


Figure 50: Costs for Germany TSOs system service Germany. Source: BNetzA (23),

5.4.3 Consumption and demand

→ Annual consumption

The annual consumption for the year 2015 was around 520,600 GWh, being the consumption per capita 6335 kWh. As German population and industry is huge compared to other countries', its annual consumption is higher and it also is its per capita one.

→ Annual consumption distribution

The following figure represents the consumption distribution of electricity in Germany for the year 2016, the industry keeps the major part of the consumption distribution.

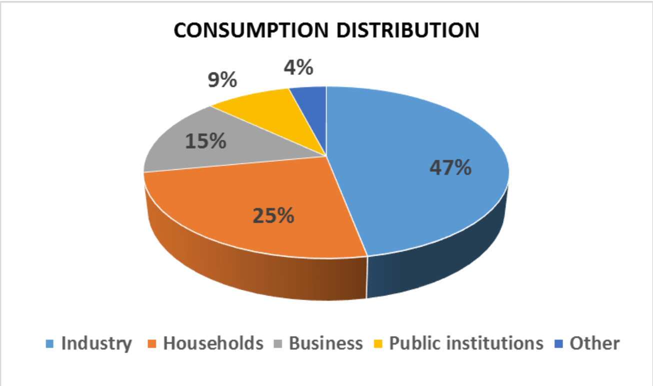


Figure 51: consumption distribution Germany. Source: Cigre (26),

→ Instantaneous peak power demand and minimum power demand

The maximum power demanded during the year 2015 was 79.46 GW, it is much less than the maximum installed capacity of 204.04GW, while the minimum load was 38.98 GW.

→ International exchanges of electricity

The geographical situation of Germany allows it to exchange electricity with a lot of neighbour countries that it shares borders with, as it is shown in the next figure for the year 2015.

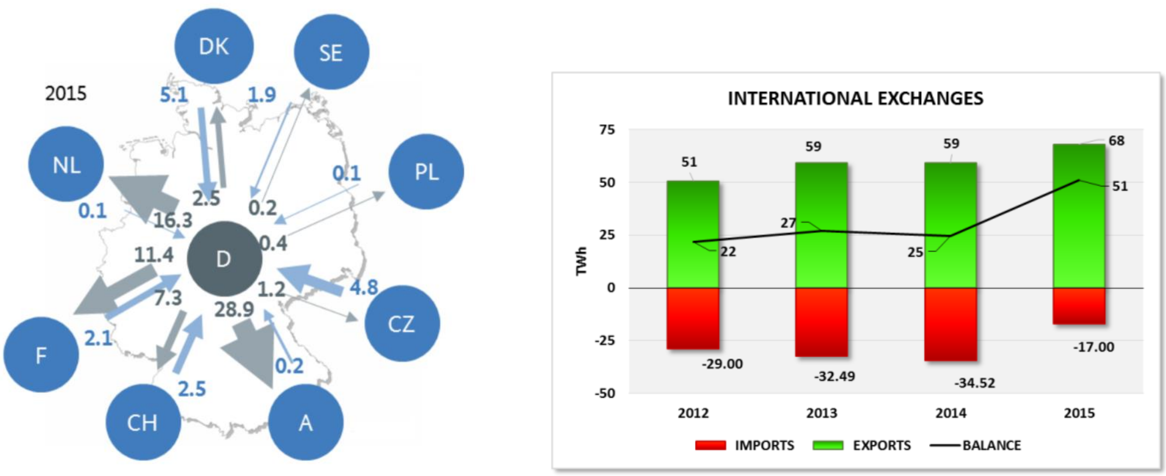


Figure 52: Interconnexions and exchanges Germany. Source: BNetzA (23), own development

	2012	2013	2014	2015
NET EXCHANGES (TWh)	22	27	25	51

Figure 53: Net exchanges Germany. Source: BNetzA (23), own development

The previous figure represent the evolution of the imports and exports by years and finally the table is the result of the net balance of electricity for the period. Germnay, as it is shown, is principally an exporter country of electricity, achieving a total of 51 TWh of net balance during 2015.

The next image represents the german export and import revenues and costs from 2011 to 2015. As it occurs with the net balance of the table, the export surplus increases year by year mainly because of the reduction of the total import costs

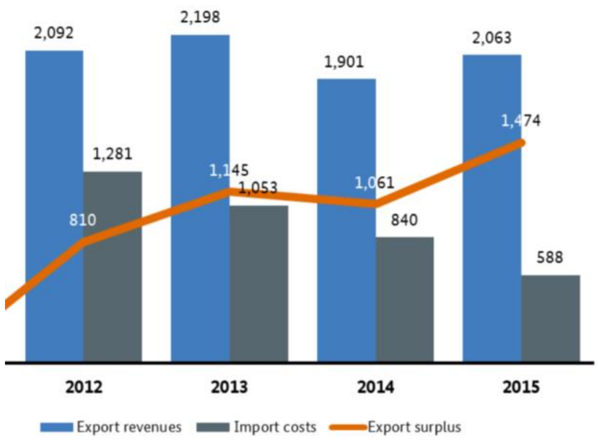


Figure 54: revenues and cost due to exchanges Germany. Source: BNetzA (23)

5.4.4 Market

→ Market coupling-General principle

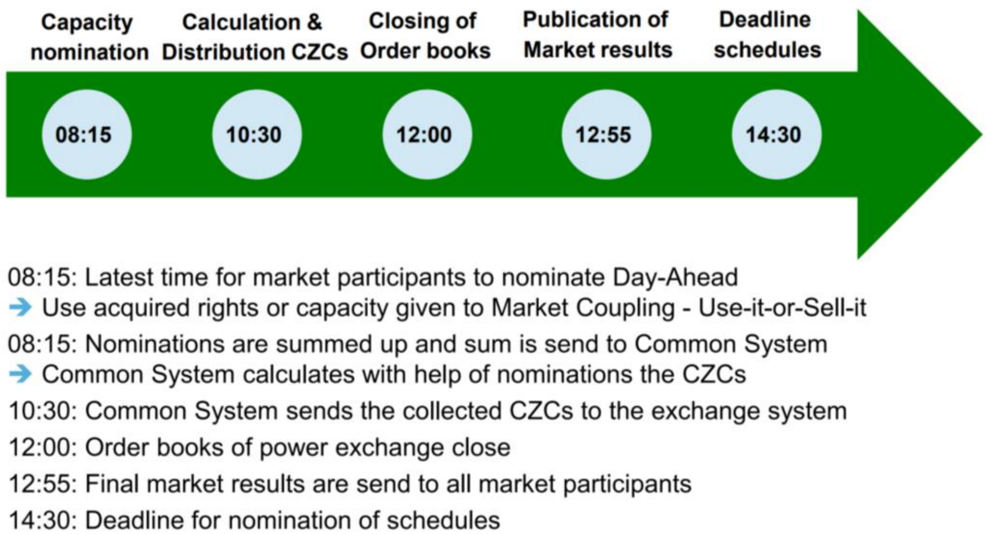


Figure 55: Market coupling timetable Germany. Source: Cigre (26)

→ **Annual electricity spot market prices - Day ahead auction**

The next tables represent the average in the annual electricity spot market prices for the daily market in Germany for the years 2012 to 2016 and also a monthly division for the years 2015 and 2016.

	2015	2016
Jan	28.77	27.93
Feb	21.53	36.66
Mar	23.83	30.63
Apr	24.07	29.04
May	21.46	25.32
Jun	27.79	30.16
Jul	26.80	34.54
Aug	26.92	31.54
Sep	30.35	31.47
Oct	36.88	39.78
Nov	37.36	31.71
Dec	34.95	27.23
Year	**29.0**	**31.6**

Figure 56 Average Monthly Price (€/MWh). Source: energy-charts (25), own development

	2012	2013	2014	2015	2016
Historic data €/MWh	42.60	37.80	32.8	31.6	29.0

Figure 57 Evolution of the middle price of the daily market (€/MWh) Source: energy-charts (25), own development

→ **Annual electricity spot market prices – Intraday**

The next tables represent the average in the annual electricity spot market prices for the intraday market in Germany for the years 2015 to 2016 as well as a monthly division.

	2015	2016
Jan	27.93	32.11
Feb	36.66	22.62
Mar	30.63	23.85
Apr	29.04	24.14
May	25.32	23.89
Jun	30.16	29.14
Jul	34.53	28.18
Aug	31.54	27.29
Sep	31.47	32.15
Oct	39.78	39.44
Nov	31.71	38.66
Dec	27.23	43.07
Year	**33.31**	**30.53**

Figure 58 Evolution of the middle price of the daily market (€/MWh) Source: energy-charts (25), own development

→ Network tariffs

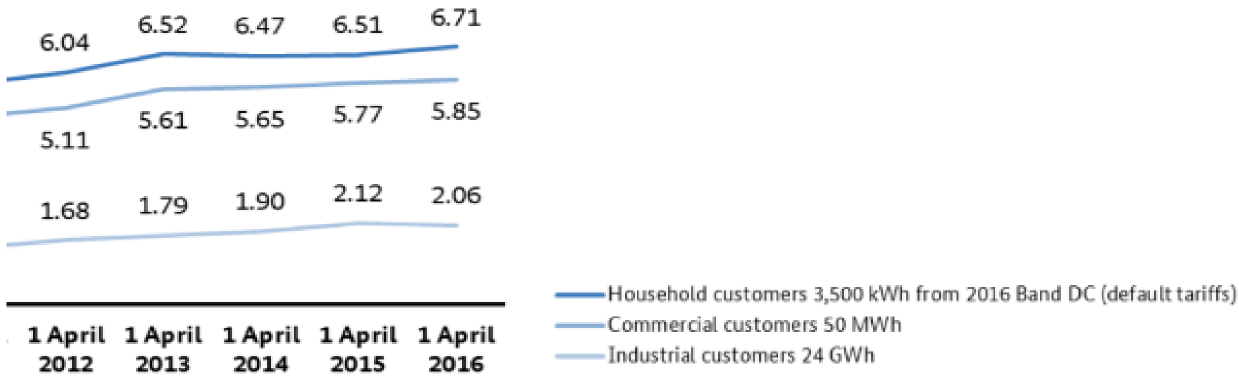


Figure 59 Network tariffs (including billing, metering and meter operation) (ct/kWh) Source: BNetzA (23)

The above figure shows the average network tariffs for standard consumers for Germany for the years 2012 to 2016.

→ Development of average spot market prices on EPEX SPOT

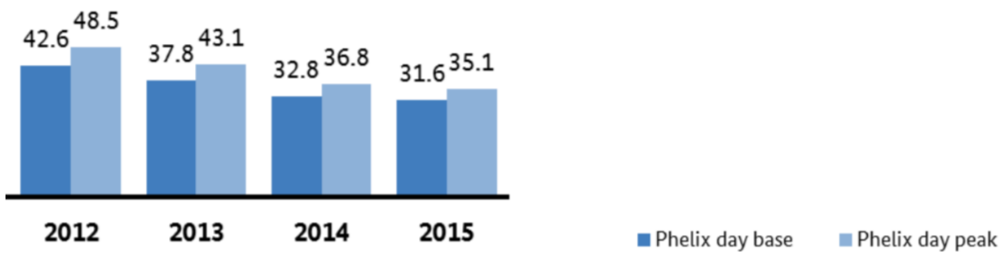


Figure 60 Development of average spot market prices on EPEX SPOT (€/MWh) Source: BNetzA (23)

The above figure shows the average spot market prices on EPEX SPOT for the years 2012 to 2015 representing a small reduction year by year.

→ Development of annual averages of Phelix front year future prices on EEX

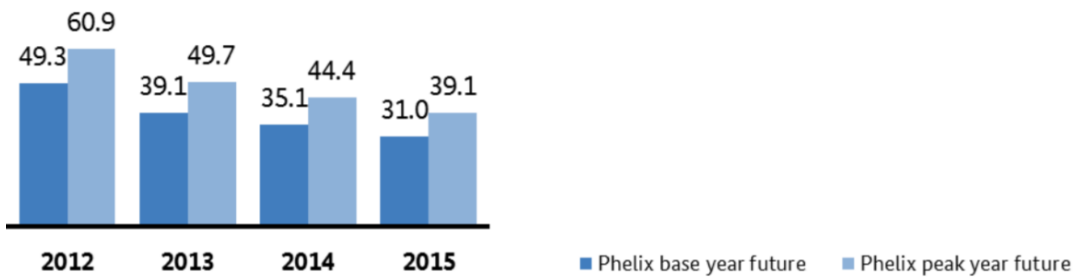


Figure 61 Development of annual averages of Phelix front year future prices on EEX (€/MWh) Source: BNetzA (23)

The above figure shows the annual averages of Phelix front year future prices on EEX for the years 2012 to 2015 and can be extracted a decreasing trend every year.

5.5 France

<u>Current legislation and regulation in France</u> (27)

The main laws concerned to the energy power sector (electricity) in France are:

- Directive 2009/72/EC concerning common rules for the internal market in electricity
- Grenelle II Law 2010
- Energy. The law created a regional climate, air quality and energy plan, introduced a carbon balance and a new regime for the installation of wind farms.
- Electricity Act 2010 (Loi NOME du 7 décembre 2010)

<u>Main agents in the electric system</u>

There exist different organisms in charge of the electricity sector in France, being the most important the following:

→ CRE. Created in 2000, the CRE is the main regulatory authority dedicated to the energy sector in France. Its role is to ensure the proper operation of the electricity and gas markets, in accordance with the energy policy's objectives and for the benefit of final consumers.

The CRE has a wide range of responsibilities, including (Energy Code):

- Ensuring access to the public electricity grid.
- Ensuring the proper operation and development of the electricity grid and infrastructure.
- Ensuring the independence of network operators.
- Contributing to the development of the European electricity and gas markets.
- Contributing to the implementation of various policies to support electricity supply and generation.

→ General Directorate for Competition Policy, Consumer Affairs and Fraud Control (Direction générale de la concurrence, de la consommation et de la répression des fraudes) (DGCCRF)

The DGCCRF is a Directorate of the Ministry of Economy in charge of controlling compliance with competition and consumer rules.

→ National Energy Mediator (Médiateur National de l'Energie) (MNE)

The NEM is an out-of-court intermediary for the settlement of disputes arising out of the execution of contracts with energy companies.

<u>Generation</u>

Although the generation sector has been entirely open to competition since 2007, the number of generating companies in France has not grown substantially. Currently, the three companies involved in generation in France are:

- EDF.(generates almost 90% of France's electricity)
- Compagnie Nationale du Rhône (CNR).

- Endessa France.

<u>Transmission and distribution organisms</u>

Réseau de transport d'électricité (RTE), a subsidiary of EDF created in 2000, is the electricity transmission system operator for France. Its public service mission is to ensure fair access to the electricity network for all participants in the electricity market.

Figure 62: Logo Rte France. Source: Rte (28)

Enedis (previously known as ERDF) is the main distribution network operator for France. It is the distribution operator for almost 95% of the French territory. The remaining 5% is managed by local distribution companies. Enedis is a public limited company created in 2008, and it is a subsidiary of EDF as well.

<u>Electric indicators</u>

This section presents the electric indicators evolution and analysis for the period 2012-2015 for the country of France excluding the territories overseas. Thus, as it has been done for Spain and Germany, the items analysed will be:

5.5.1 Generation

→ Installed power capacity

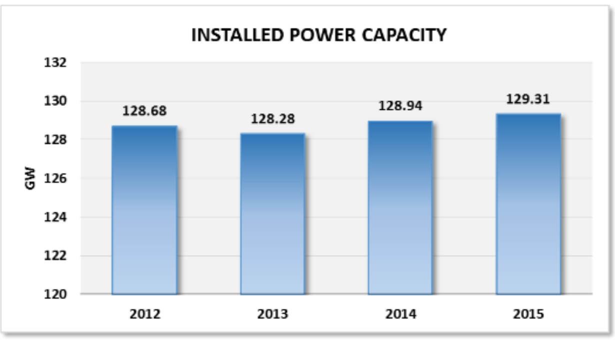
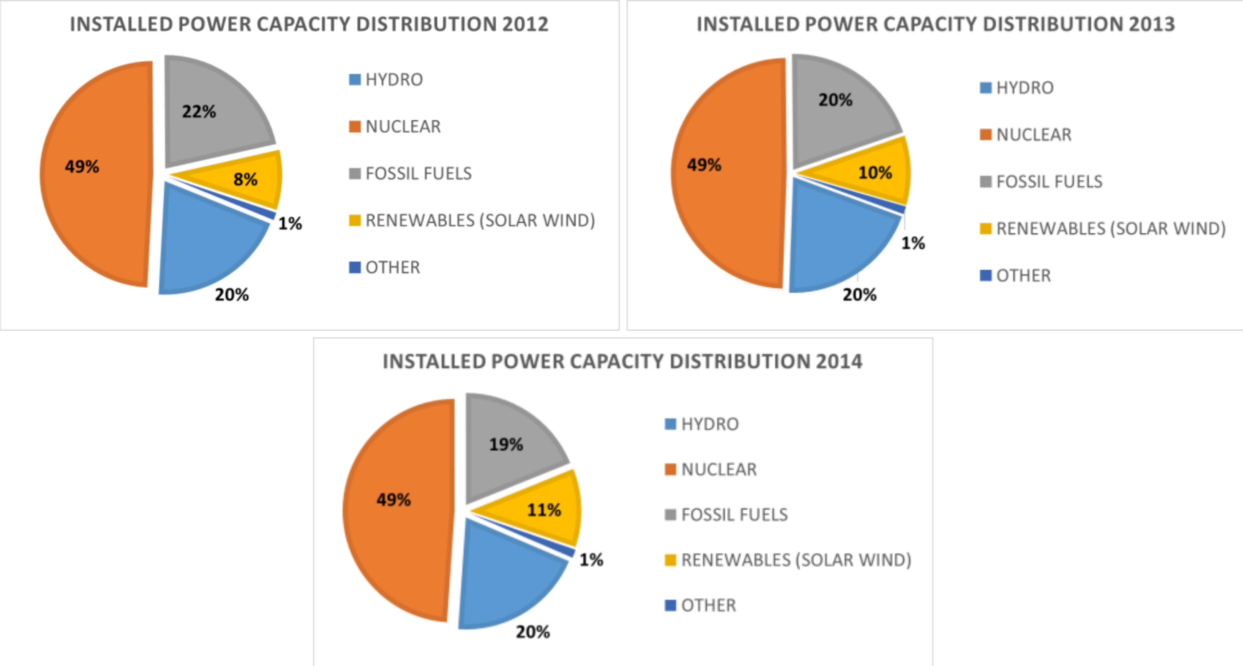
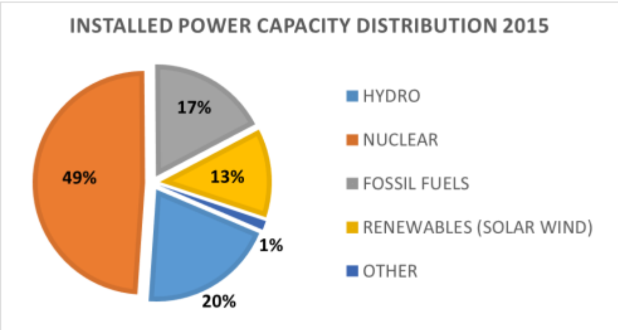


Figure 63: Installed power capacity France. Source: Rte (29), own development

The graph above shows the evolution of the installed capacity during the years 2012 to 2015. The installed capacity practically remains constant along the years, being 2015 the year with higher capacity with an amount of 129.31 GW.

→ Installed power capacity distribution by technology





TECHNOLOGY	GW
HYDRO	25.47
NUCLEAR	63.10
FOSSIL FUELS	22.49
RENEWABLES (SOLAR WIND)	16.55
OTHER	1.68
TOTAL	**129.31**

Figure 64: Installed power capacity distribution France. Source: Rte (29), own development

The previous charts show the evolution for France during the years 2012 to 2015 of the distribution of the installed power capacity. As it occurs with the installed power capacity, the variations are not significant. Nevertheless, the share that fossil fuels technology losses goes to renewable generation every year. The nuclear energy accounts for half of the installed capacity in France. Also, the table presents the installed power capacity in 2015 in term of power.

→ Annual electricity production (absolute values)

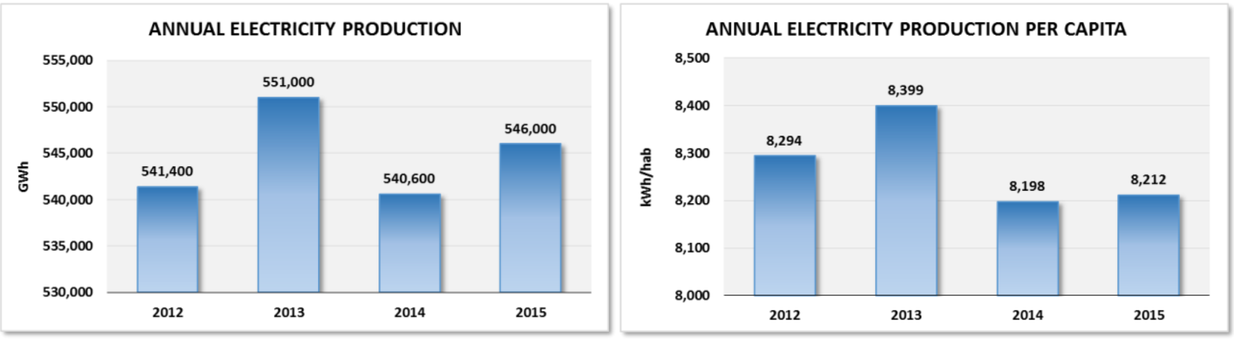
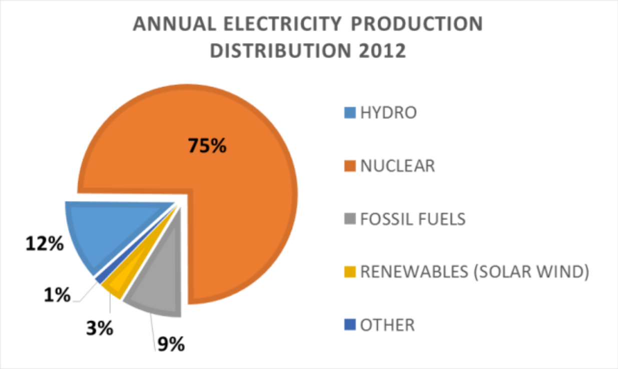
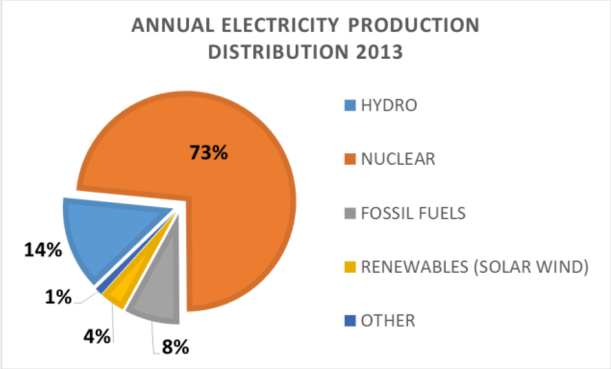


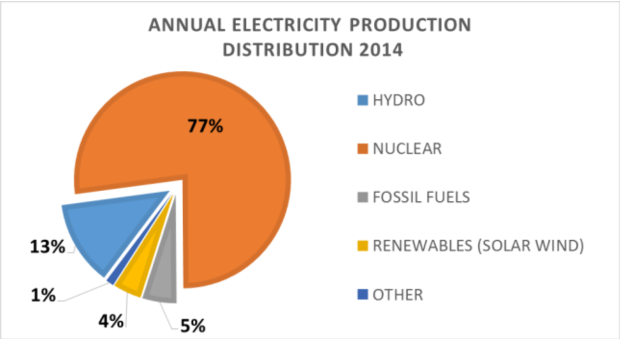
Figure 65: Annual electricity production France. Source: Rte (29), own development

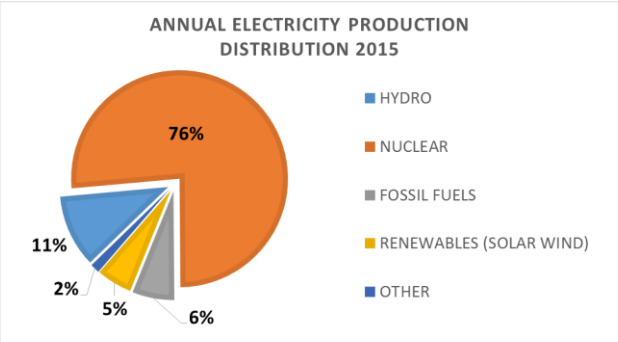
The graphs above represent the annual electricity production in France and the consumption per capita respectively. As it occurs with other countries the annual production increases every year without taking into account 2013 when the high temperatures make the consumption to be higher. France is still having one of the highest amounts of electricity production per capita in comparison to other European Union countries due to the huge amount of nuclear power stations the country

→Annual electricity production distribution by technology (%)









TECHNOLOGY	GWh
HYDRO	58,968
NUCLEAR	416,598
FOSSIL FUELS	33852
RENEWABLES (SOLAR WIND)	28,938
OTHER	7,644
TOTAL	**546,000.**

Figure 66: Annual electricity production distribution France. Source: Rte (29), own development

The graphics above present the evolution in the annual production distribution for France during the years 2012 to 2015 while the table is the distribution of the annual production by technology for 2015 in term of power. The most significant data that can be extracted is the nuclear energy share, if in the installed capacity nuclear power represented a half of the total capacity in the production nuclear energy reaches a 76% and 416598GW of the total generation.

→ Real time information of the grid

The image below represent the electricity generation for a specific day in 2017 in France. There exists the possibility of following online the status of the electricity grid. The webpage "rte-france.com" gives information of the demand, the different sources of electricity and other interesting data of the generation of electricity at real time and historical data of it.

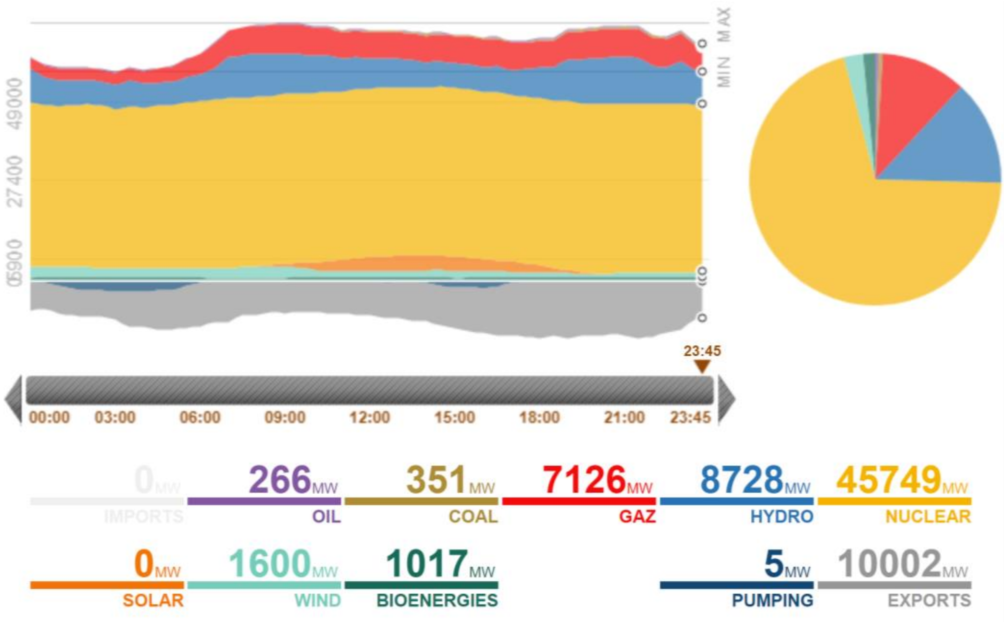


Figure 67: Real time generation France, 27/3/2017. Source: Rte (28), own development

→ CO2 emissions due to electricity production

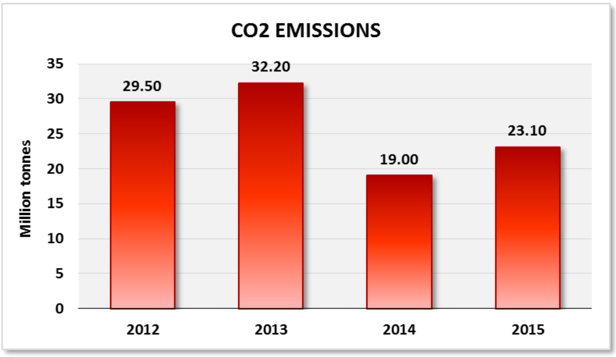


Figure 68: CO2 emissions France. Source: Rte (29), own development

The chart above collects the amount of CO2 emitted to the atmosphere due to the generation of electricity. As it can be expected, the CO2 emissions are much less than in other countries even with much less electricity production because of the fact that the nuclear energy generation does not produce CO2 in comparison with the large emitters of gases of the fossil fuel power stations.

→Integration of renewables (%):

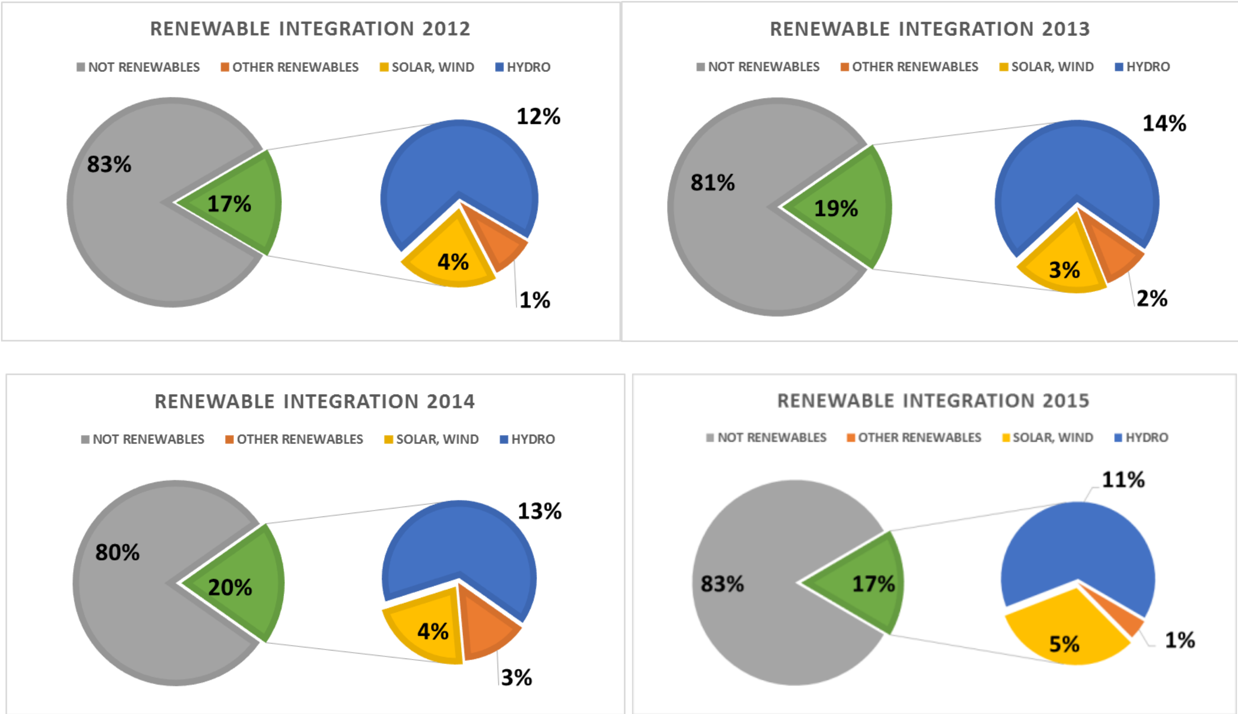


Figure 69: Renewable integration France. Source: Rte (29), own development

The figures above show the evolution of the integration of renewable in France. The small percentage of renewables is mainly represented by the hydro, while other technologies as wind or solar are smaller even though they are increasing year by year.

5.5.2 Network. Transmission and distribution.

→Nominal power of the interconnexion transmission and distribution lines:

The interconnexion network correspond to voltage levels of 400kV while the transmission grid voltages are higher to 220kV and finally the regional distribution networks can be divided in 225 90 and 63 kV.

→Length of the transmission system

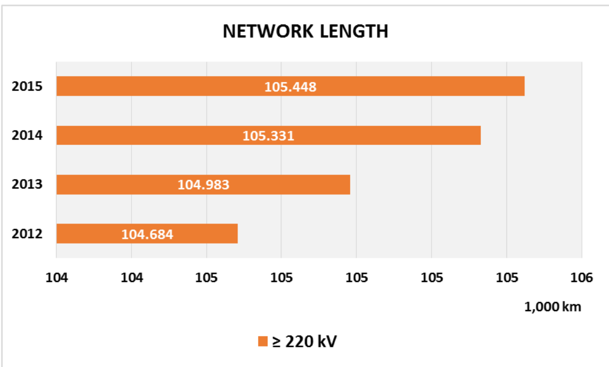


Figure 70: Transmission network length France. Source: Rte (29), own development

The above chart shows the length of the transmission system for France. During the observed years the high voltage grid has increased little by little each year, being the French transmission system one of the most consolidated network grids in the world

→ Average interruption time

For the year 2015 the average interruption time for the transmission network was 7.03 minutes.

→ Grid investment

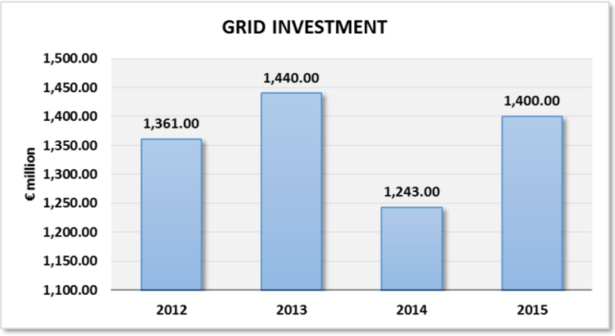
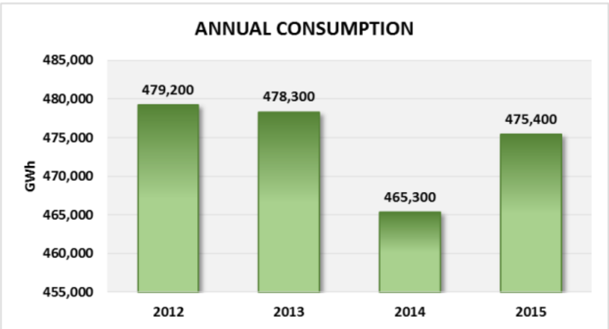


Figure 71: Grid investment France. Source: Rte (29), own development

The above graph shows the grid investment since the year 2012 to 2015 in France. The money invest is around 1,400 million € every year.

5.5.3 Consumption and demand

→Annual consumption



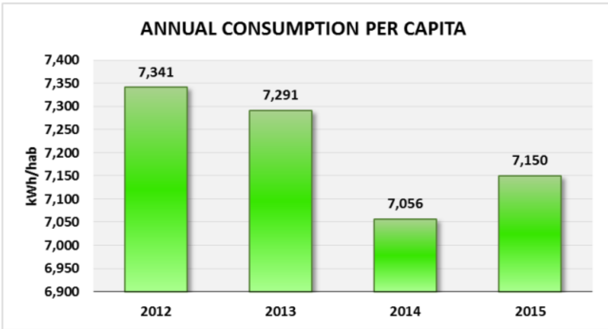


Figure 72: Annual consumption France. Source: Rte (29), own development

These charts are the representation of the annual consumption in France during the years 2012 to 2015. The consumption trend is decreasing every year, however, in 2014 the consumption differs drastically due to the weather conditions.

→Breakdown by segment of consumption.

The next chart shows the breakdown by segment of consumption in France for the year 2015, showing that the residential group is the leader in the consumption amount followed by the business and the heavy industry.

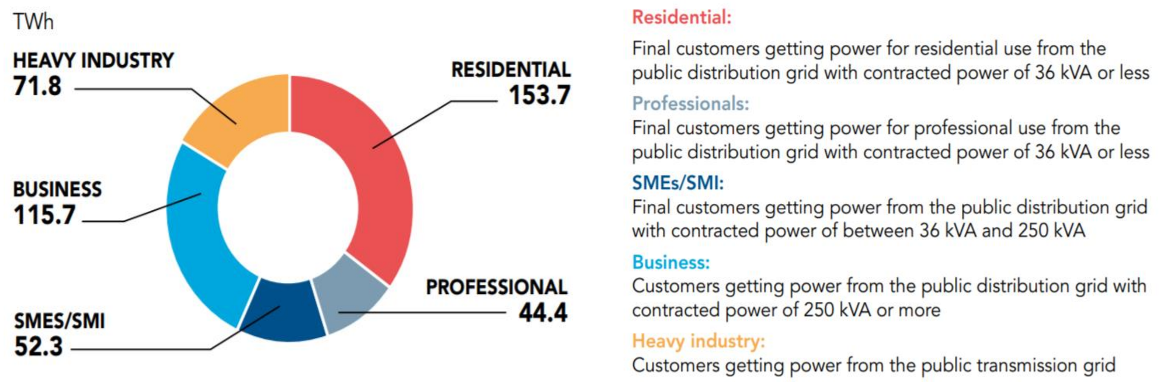


Figure 73: Consumption breakdown France. Source: Rte (29).

→ Instantaneous peak power demand

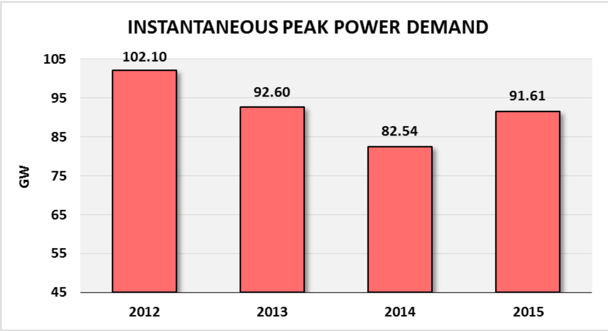


Figure 74: Instantaneous peak power demand France. Source: Rte (29), own development

The above graph shows the evolution of the instantaneous peak power demand, the trend decreases until 2014 and then increases again in 2015, mainly due to prevoously mentioned weather conditions in 2014 that have decreased the instantaneous load in a big way. The maximum instantaneous power demand in 2015 is relatively close to the installed capacity during that year, which was about 129.31 GW. On the oher hand, the minimum power demanded during 2015 was 29.56 GW.

→ International exchanges of electricity

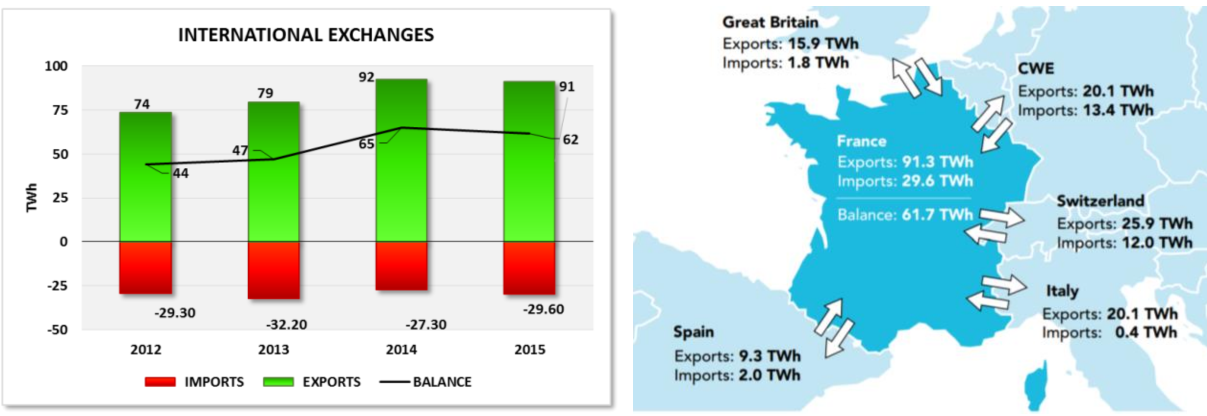


Figure 75: Map and balance of international exchanges France. Source: Rte (29), own development

Figure above how the international exhanges of electricity in France during the years 2012 2013 2014 and 2015. Every year the amount of energy exported is higher than the amount of electricity imported, so as it is derived from the net balance in next table, France is a huge exporter of electricity.

Finally, the map represents the interconnections of France with its neighbour countries and the energy exchanged with all of them during the year 2015.

	2012	2013	2014	2015
NET EXCHANGES (TWh)	44	47	65	62

Figure 76: Annual electricity exchanges France. Source: Rte (29), own development

5.5.4 Market

→ Evolution of the middle price of the daily market

Next figure represents the evolution of the price of the daily market in France for the years 2012 to 2016

	2012	2013	2014	2015	2016
Historic data €/MWh	46.9	43.20	34.70	38.50	36.70

Figure 77: Evolution of the middle price of the daily market France. Source: CRE (30), own development

→Evolution of the intraday price in France

Next figure represents the evolution of the price of the intraday market in France for the years 2012 to 2016, as it occurs with the daily market there is a decreasing trend in the prices.

	2012	2013	2014	2015	2016
Historic data €/MWh	47.00	44.34	35.01	38.78	36.70

Figure 78: Evolution of the intraday price France. Source: CRE (30), own development

→ Development of average spot market prices on EPEX SPOT

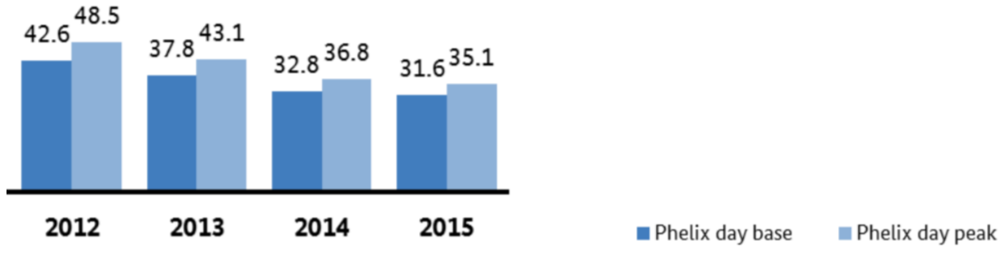


Figure 79 Development of average spot market prices on EPEX SPOT (€/MWh) Source: BNetzA (23)

The above figure shows the average spot market prices on EPEX SPOT for the years 2012 to 2015 representing a small reduction year by year.

→ Development of annual averages of Phelix front year future prices on EEX

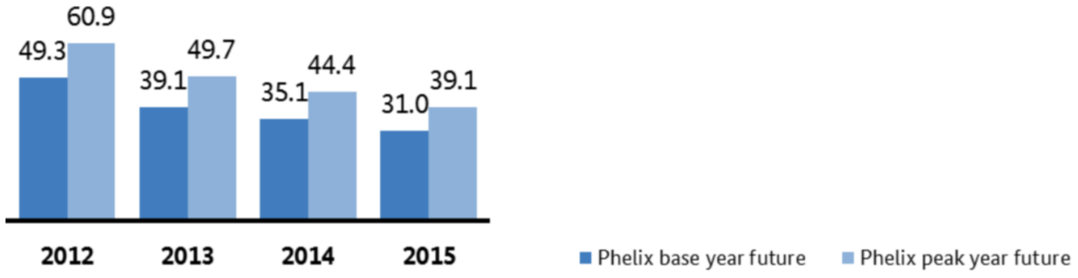


Figure 80 Development of annual averages of Phelix front year future prices on EEX (€/MWh) Source: BNetzA (23)

The above figure shows the annual averages of Phelix front year future prices on EEX for the years 2012 to 2015 and can be extracted a decreasing trend every year.

5.6 The United Kingdom

Current legislation and regulation in the United Kingdom (31)

The regulatory framework in Great Britain (England, Wales and Scotland) (GB) operates through system legislation, licences and industry codes with an independent regulator. The main laws that regulate the energy sector are the following:

→ Electricity Act 1989

- Establishes a licensing regime.
- Sets out the statutory duties of the regulator, the Gas and Electricity Markets Authority (GEMA), which operates through the Office of Gas and Electricity Markets (Ofgem) and the Secretary of State for Energy and Climate Change (Secretary of State).

→ Utilities Act 2000

- Energy Act 2013 2011 2010 2008

→ Industry codes

- Connection and Use of System Code (CUSC
- Balancing and Settlement Code (BSC)
- Grid Code.
- System Operator–Transmission Owner Code (STC).
- Master Registration Agreement (MRA)
- Distribution Connection and Use of System Agreement (DCUSA).
- Distribution Code.

Main agents in the electric system

→ Department of Energy & Climate Change (DECC)

- Government department responsible for energy policy in Great Britain (England, Wales and Scotland).

→ Department of Enterprise, Trade and Investment in Northern Ireland (DETI)

→ Government department responsible for energy in Northern Ireland as well as for economic policy development, enterprise, innovation, telecoms, tourism, health and safety at work, insolvency service, consumer affairs, and labour market and economic statistics services.

→ Gas and Electricity Markets Authority (GEMA)

- Regulates the electricity and gas markets in Great Britain (England, Wales and Scotland).

→ Utility Regulator (UR)

- Regulates electricity, gas, water and sewerage industries in Northern Ireland.

→ Health and Safety Executive (HSE)

- Responsible for health and safety matters such as offshore development and electrical safety.

→Office for Nuclear Regulation (ONR)

- Responsible for nuclear sector regulation across the UK (England and Wales).

Generation

Since the privatisation of the generation industry in the early 1990s leading to three generating companies (National Power, Powergen and Nuclear Electric), the number of generating companies in Great Britain (England, Wales and Scotland) has grown considerably.

Transmission and distribution organisms

National Grid Electricity Transmission (NGET) (32) is the licensed national electricity transmission system operator for Great Britain. Ownership of the transmission assets is more mixed:

There are six licensed distribution network operators (DNOs) in Great Britain, each responsible for one or more of the 14 distribution services area:

- Electricity North West.
- Northern Powergrid.
- Scottish and Southern Energy.
- SP Energy Networks.
- UK Power Networks.
- Western Power Distribution.

Electric indicators

This section presents the data obtained for the electric indicators in the United Kingdom (area excluding the overseas territories) for the 2012-2016 period.

5.6.1 Generation

→ Installed power capacity

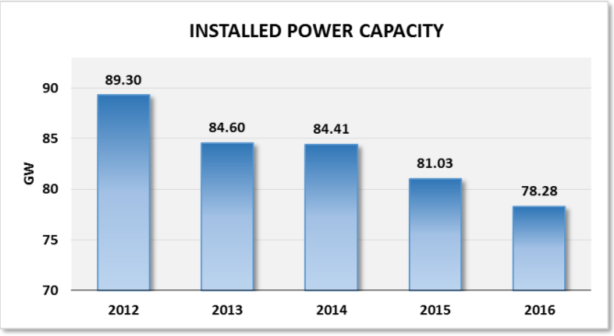


Figure 81: Installed power capacity UK. Source: Gov UK (33), own development.

The table above shows the evolution in the installed power capacity during years 2012 to 2016. There is a progressive reduction in the maximum power capacity, and it can produce from 89.30 GW to 78.28GW in 2016.

→ Map of the main power generators and its location and share of generation output.

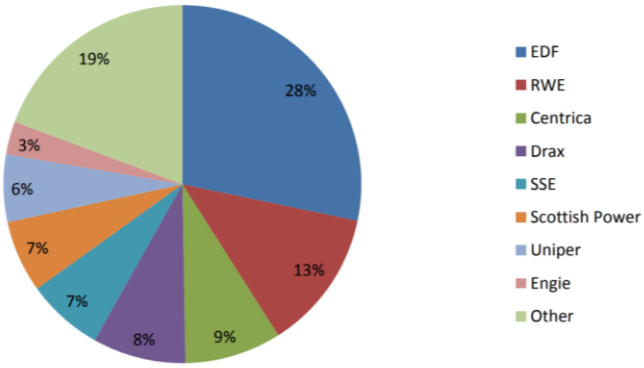
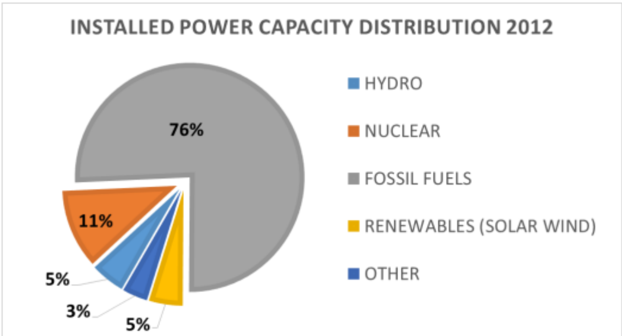
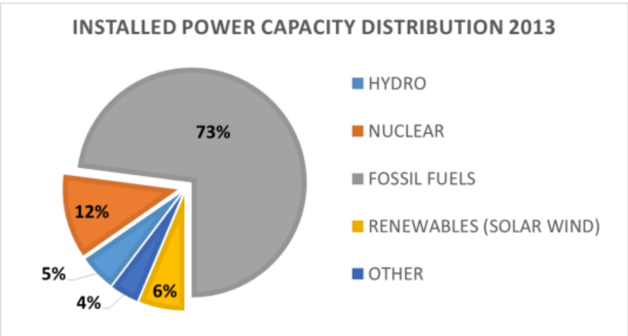


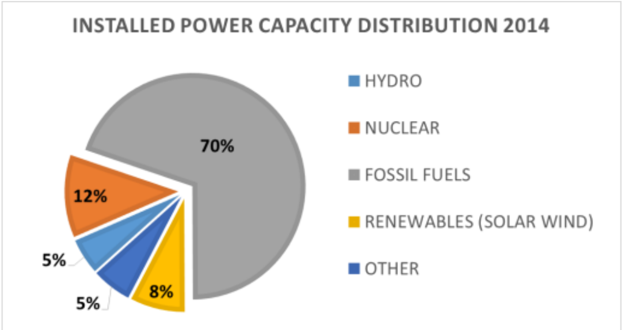
Figure 82: Map of the main power generators and its location and share of generation output U. Source: Gov UK (33).

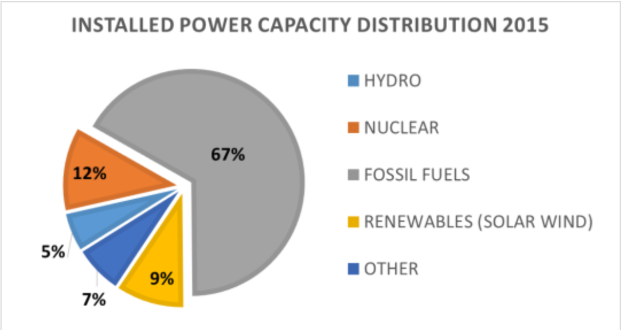
Images above show the distribution by company in terms of generation for the year 2015 and its location in a map. It is concluded that the hydro is more abundant in the north, coinciding with the region that has a higher reserve of water while the centre and the south the fossil fuel power stations are predominant.

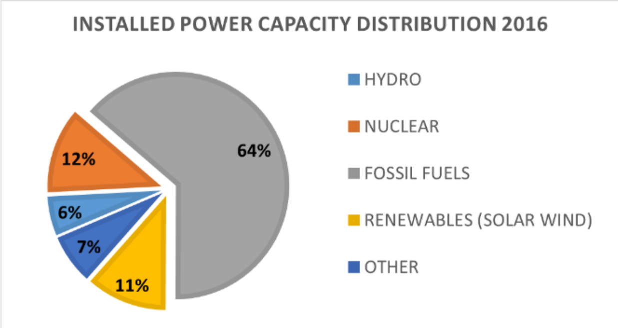
→Installed power capacity distribution by technology











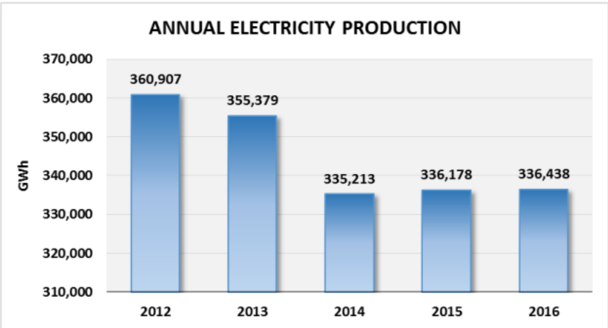
TECHNOLOGY	GW
HYDRO	4.35
NUCLEAR	9.50
FOSSIL FUELS	49.91
RENEWABLES (SOLAR WIND)	9.00
OTHER	5.53
TOTAL	**78.28**

Figure 83: Installed power capacity distribution UK. Source: Gov UK (33), own development.

Above graphs show the evolution by percentage of the installed power capacity distribution in terms of type of technology. While some technologies like nuclear power remain constant over the years, the renewables increase its ratio and there is a third group by the fossil fuels which reduces its proportion.

The table shows the distribution of the installed power capacity in terms of technology for the year 2016. More than a half of the capacity corresponds to those technologies relative to fossil fuels, mainly those related to coal.

→ Annual electricity production



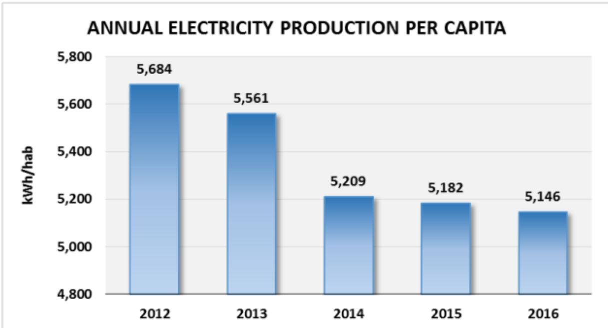
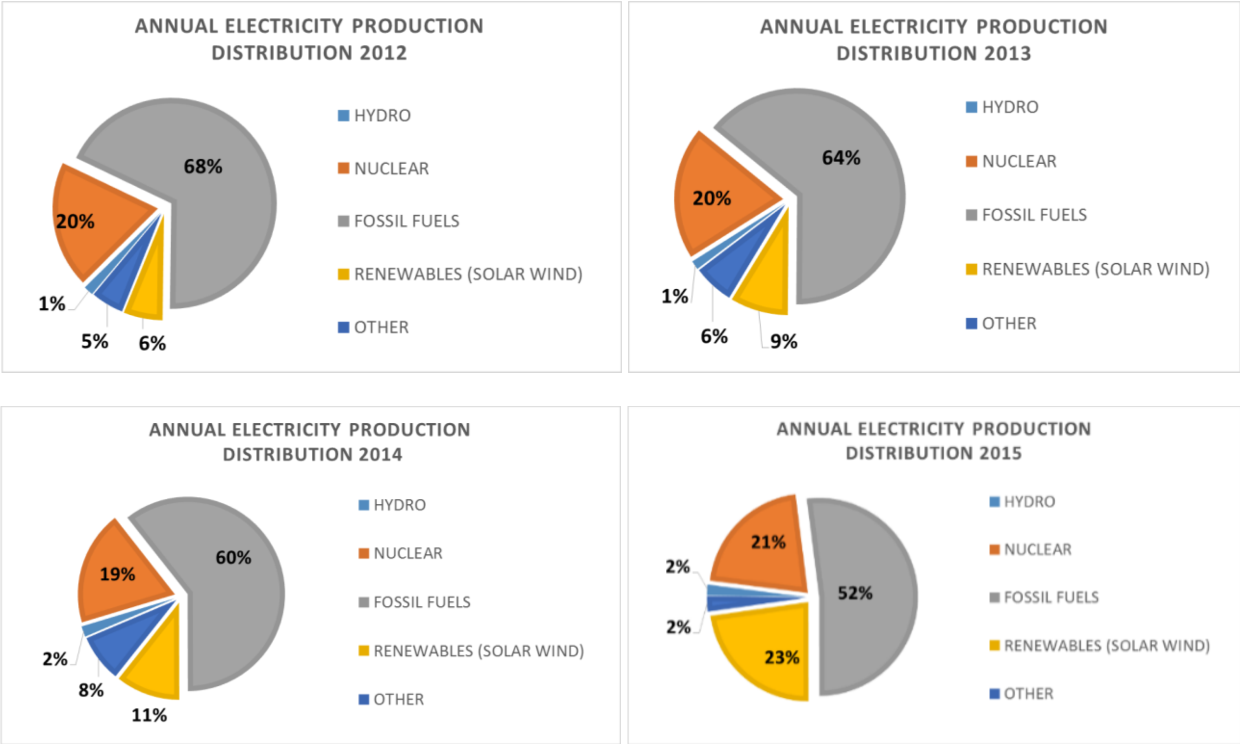


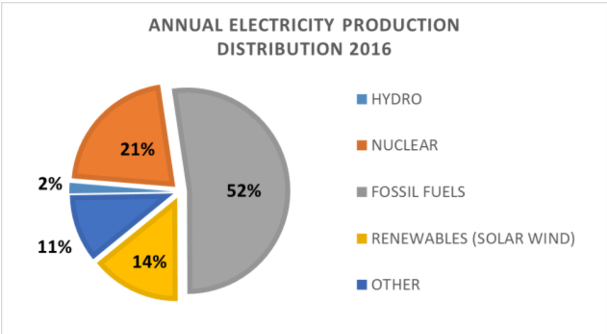
Figure 84: Annual electricity production UK. Source: Gov UK (33), own development.

The graphs above shows how the annual electricity production has evolved in the United Kingdom from the observed period.

A decrease in the starting years is shown, followed by a stagnation, probably due to the recovery from the financial crisis.

→ **Annual electricity production distribution by technology (%)**





TECHNOLOGY	TWh
HYDRO	5.40
NUCLEAR	71.73
FOSSIL FUELS	175.91
RENEWABLES (SOLAR WIND)	47.79
OTHER	35.62
TOTAL	**336.44**

Figure 85: Installed power capacity distribution UK. Source: Gov UK (33), own development.

Previous graphs show the evolution in percentage of the annual electricity production distribution in terms of technology. The nuclear power is constant but the electricity produced from fossil fuels is reduced every year in favour of the renewable technologies.

The table presents the distribution of the electricity production in the year 2016. As pointed out before, the electricity produced from fossil fuels still accounted for more than a half of the production, representing 175 TWh out of the total production.

→ Real time information of the grid

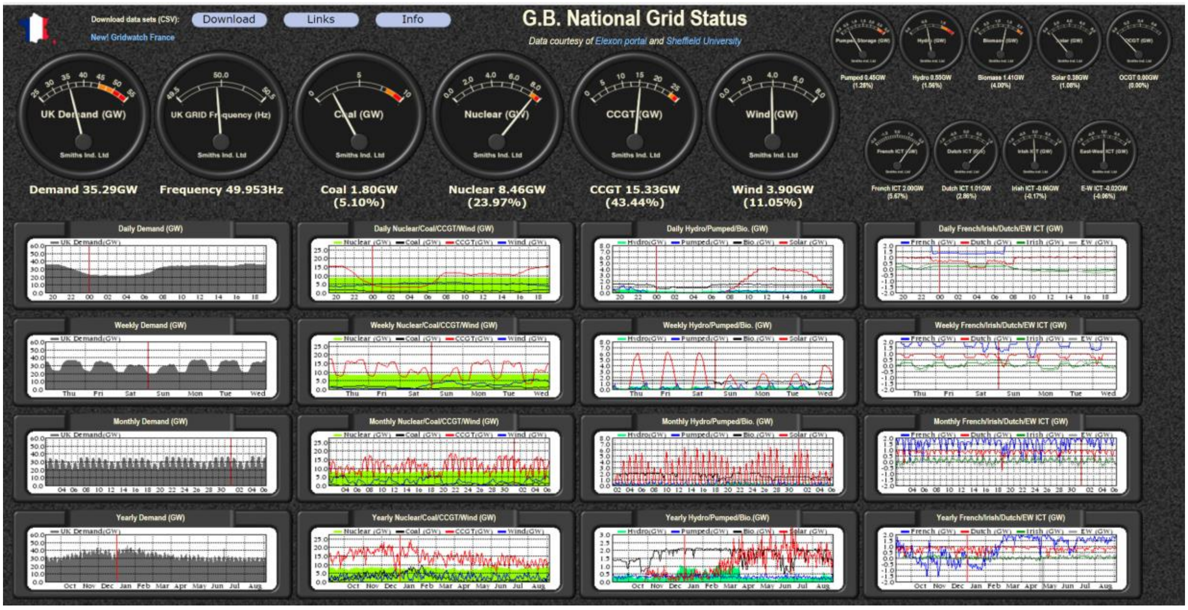


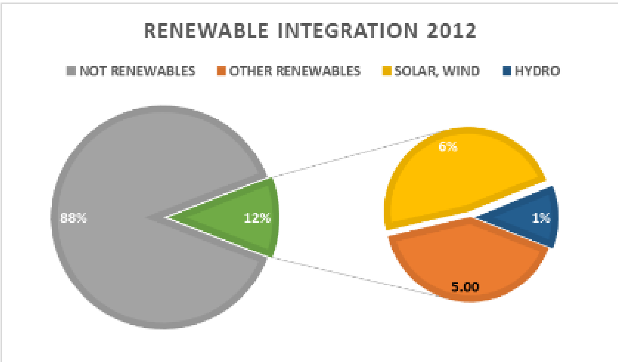
Figure 86: real time grid information UK. Source: gridwatch (34)

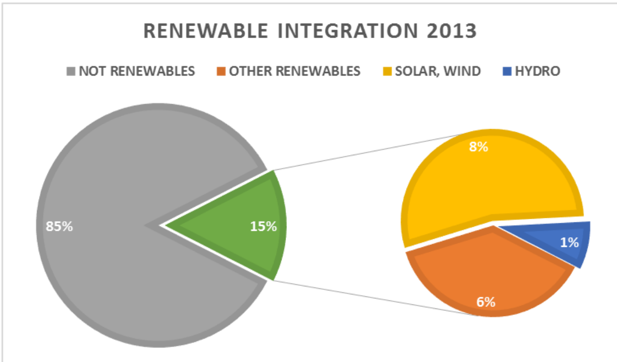
It is allowed to follow the status of the grid online for those users that are interested on it. The webpage "gridwatch.com" gives information about the demand, the different sources of electricity and other interesting data of the generation of electricity at real time. (See previous graph)

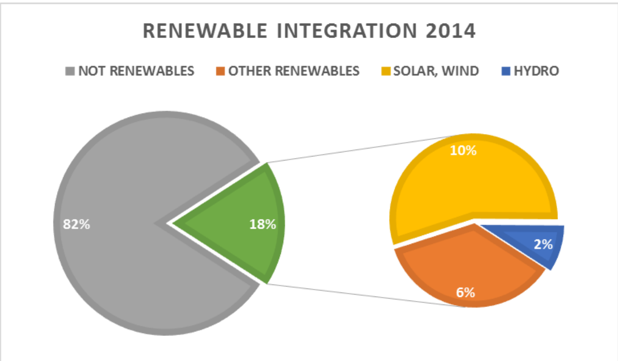
→CO2 emissions due to electricity production

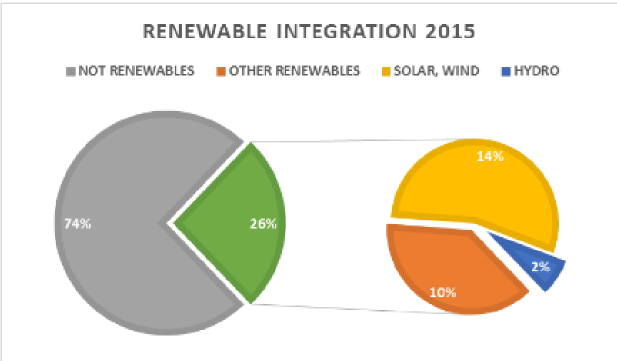
During 2015, the UK produced 111.67 million tonnes from electricity production. This quantity is higher than other European countries' mainly because the big percentage of power stations in the country that use fossil fuels to produce electricity.

→Integration of renewables (%):









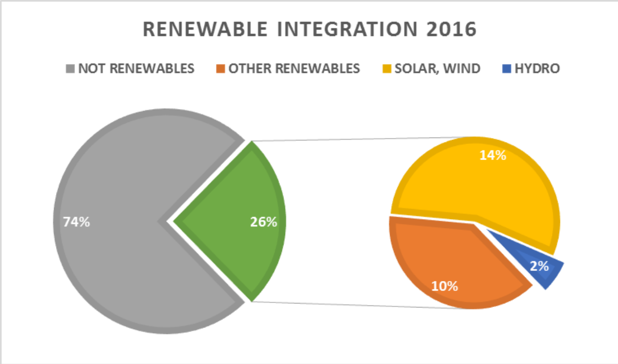


Figure 87: Renewable integration UK. Source: Gov UK (33), own development.

Graphs above show the impact of the renewable integration in the production of electricity in the United Kingdom for the years 2012 to 2016. Even though the solar technology has little impact in the generation if it is compared to other technologies as wind energy or biomass, the sum of the difference of them makes a 26% of the electricity production in the year 2016.

5.6.2 Network. Transmission and distribution.

→Nominal power of the distribution lines:

There are two voltage categories for distribution lines: those that carry between 0V - 1000V, called 'low voltage lines'; and those that carry between1000V - 50,000V, called 'medium voltage lines. For the UK the distribution provide electricity to most part of the consumers, networks between 12 kV and 230V.

→Location of the distribution system

As it has been explained, the UK has different distribution companies and each of them is in charge of one region. Next mage represents where the distribution network operator companies work.

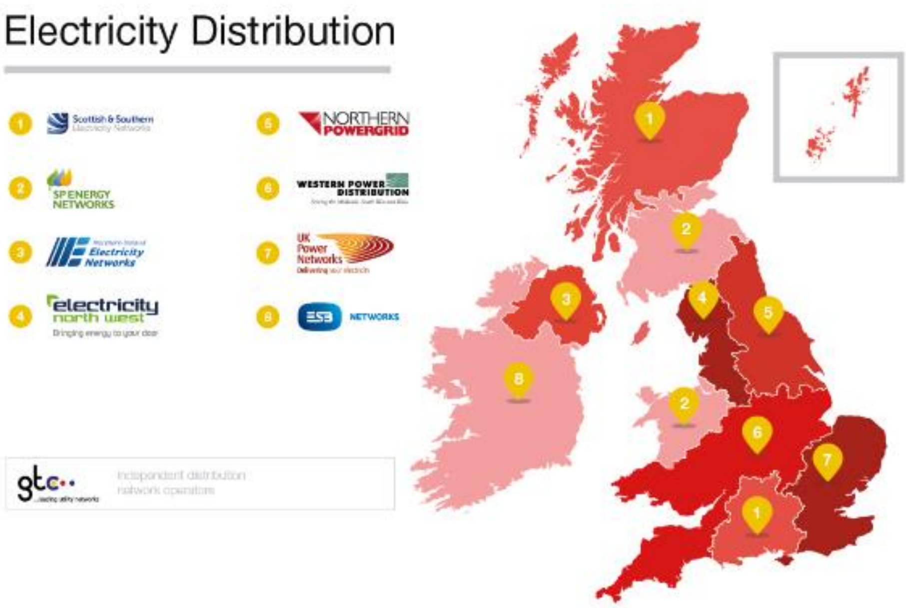


Figure 88: DSOs map UK. Source: nationalgrid (35)

→ **Power and Length of the transmission system**

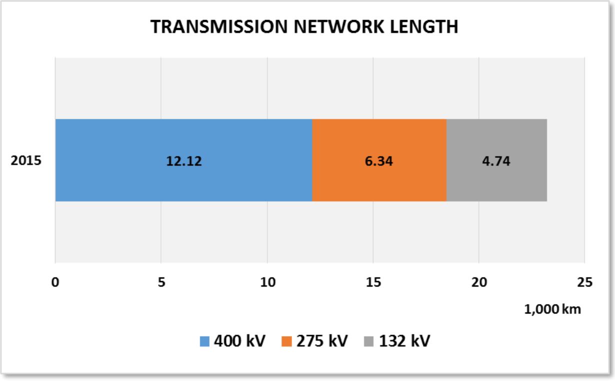


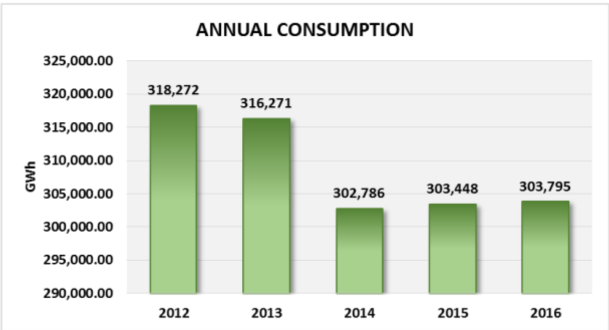
Figure 89: Transmission network length UK. Source: Gov UK (33), own development.

There are two voltage categories for these structures: those that carry between 50,000V - 200,00V, called 'high voltage lines'; and those that carryover 200,000Vcalled 'extreme high voltage lines. The main voltage levels are 132 for high voltage lines and 275 and 400 kV for extremely high voltage lines.

Previous graph shows the distribution in terms of voltage levels of the transmission lines for a total of 23,200 km of lines.

5.6.3 Consumption and demand

→ **Annual consumption**



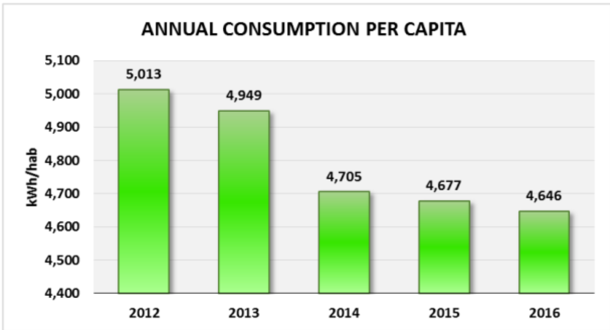


Figure 90: Annual consumption UK. Source: Gov UK (33), own development.

The previous charts represents the annual consumption for the years 2012 to 2016in UK. As it can be observed, is closed related to the demand, there is a decrease in the annual consumption of electricity and then it became stagnant

→ Instantaneous peak power demand and the minimum power demand

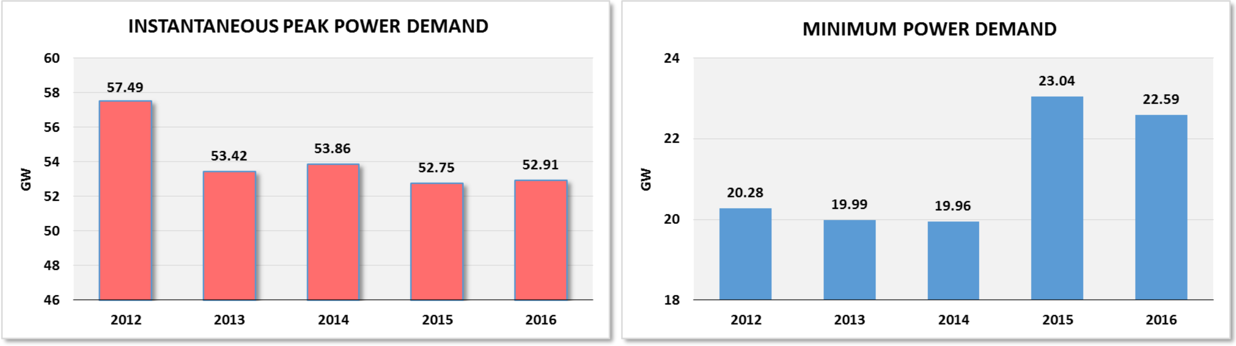


Figure 91: peak and minimum power demand UK. Source: Gov UK (33), own development.

The above graphs illustrates the maximum and the minimum demand in the UK during the period from 2012 to 2016 respectively. While the maximum peak load that during the year 2016 accounted 77.16 percent of UK electricity generation capacity decreases the minimum increases. The ideal demand would be a constant demand with small difference between them.

→ International exchanges of electricity

In the year 2017 Great Britain has 4 GW of interconnexion capacity with its neighbours. The different GW itemise in the following way:

- 2 GW to France (IFA)
- 1 GW to the Netherlands (BritNed)
- 500 MW to Northern Ireland (Moyle)
- 500 MW to the Republic of Ireland (East West)

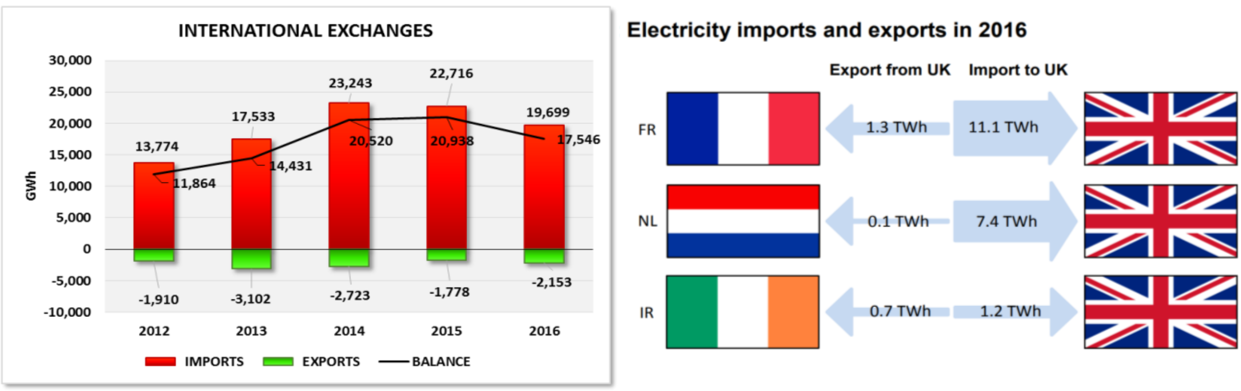


Figure 92: International exchanges map and balance UK. Source: Gov UK (33), own development.

The graph above represent the international exchanges along the years from 2012 to 2016 separating the imports and the exports and the quantity of electricity exchanged with the different countries (France Netherlands and Ireland) while the table shows the net balance of those exchanges

	2012	2013	2014	2015	2016
NET EXCHANGES (TWh)	11.864	14.431	20.520	20.938	17.546

Figure 93: Net exchanges UK. Source: Gov UK (33), own development.

5.6.4 Market

→ **Electricity prices: Day-ahead baseload contracts – monthly average (GB)**

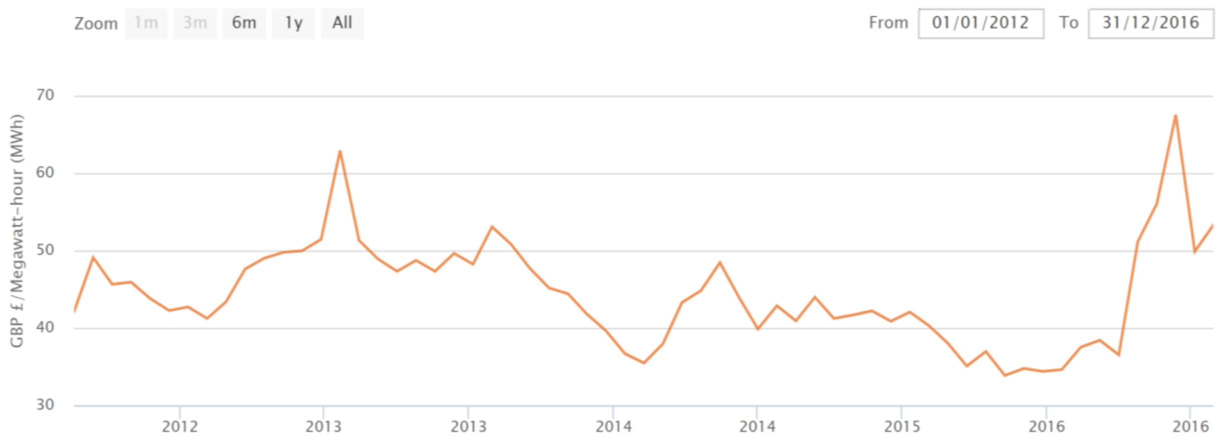


Figure 94: Day-ahead baseload contracts monthly average UK. Source: Ofgem (36), own development.

The previous figure extracted from Ofgem (the Office of Gas and Electricity Markets) shows the electricity prices: day ahead baseload contracts monthly average in Great Britain between the years 2012 to 2016. The maximum price was on November with a price of 67.54pound the MWh while the minimum one was on April reaching a value pf 34.37 pound MWh both of them in the year 2016 (when referendum of Brexit occurred)

	2012	2013	2014	2015	2016
Historic data €/MWh	42.62	40.74	42.43	50.79	45.21

Figure 95: Day-ahead baseload contracts annual UK. Source: Ofgem (36), own development.

→ **Expenditure vs allowance: Electricity distribution**

The below figure represent the expenditure vs allowance of the electricity distribution system for the year 2016.

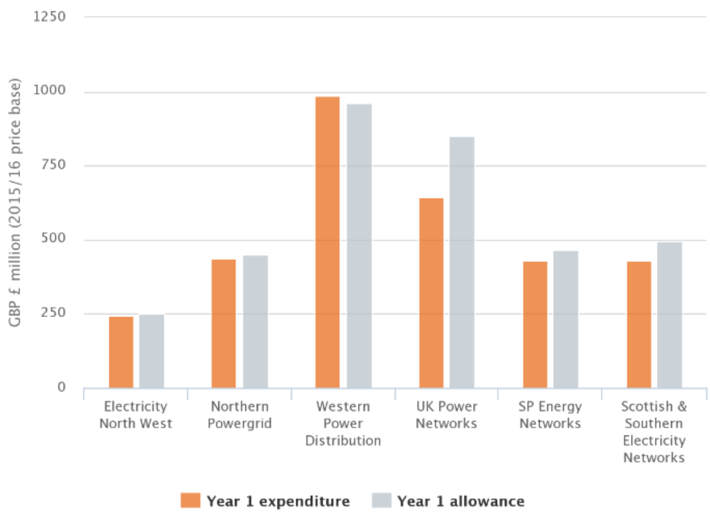


Figure 96: Expenditure vs allowance UK. Source: Ofgem (36)

5.7 Comparation of Spain, Germany, France and the United Kingdom

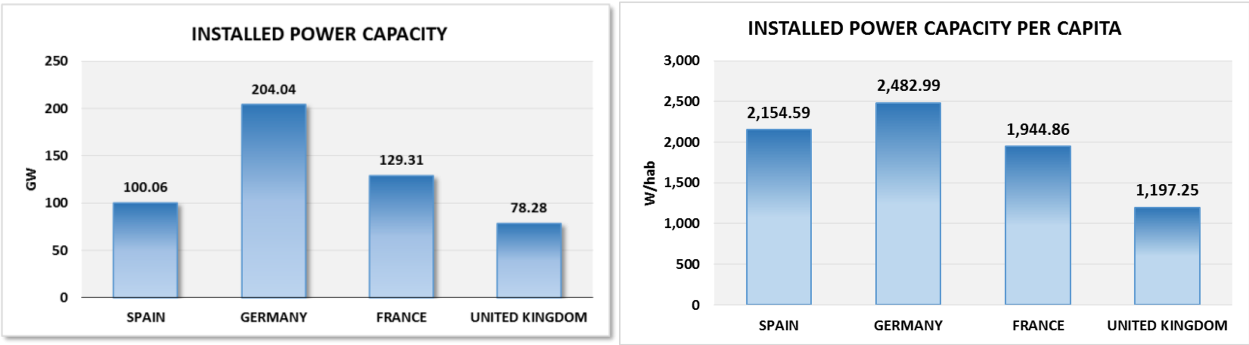


Figure 97: Installed power capacity, countries comparison. Source: Diverse[3]

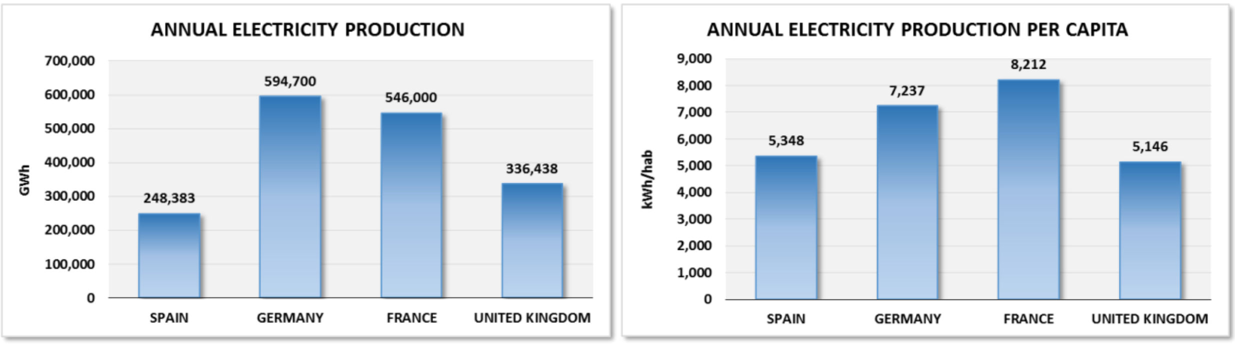


Figure 98: Annual electricity production, countries comparison. Source: Diverse

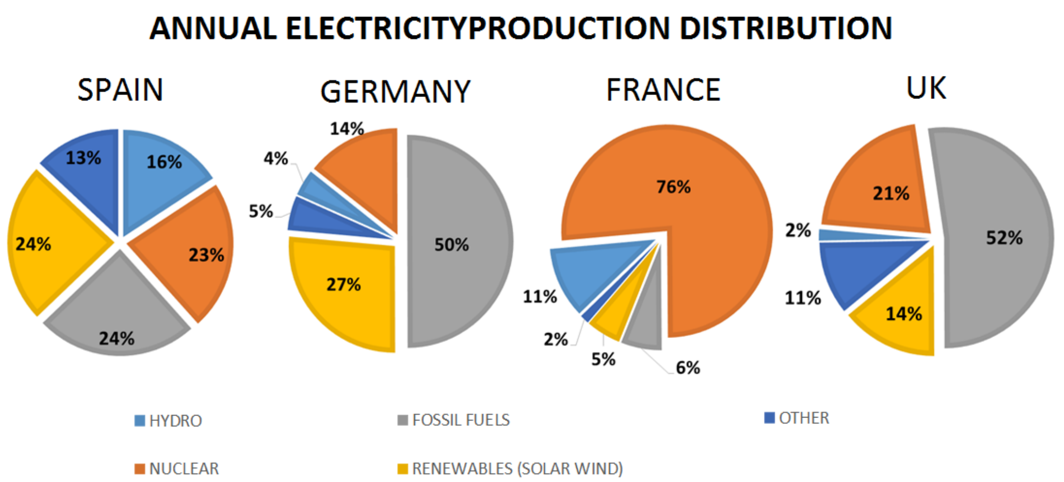


Figure 99: Annual electricity production distribution, countries comparison. Source: Diverse

[3] Diverse: compilation of the multiple sources used during this chapter collected for this section

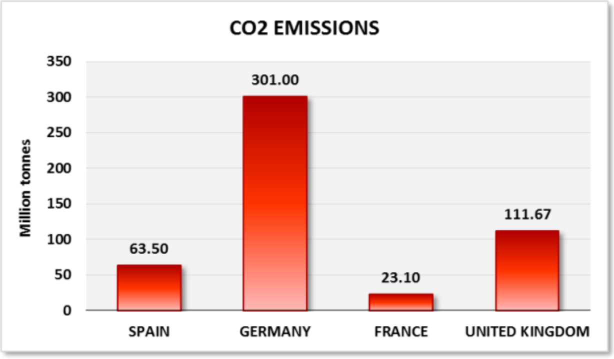
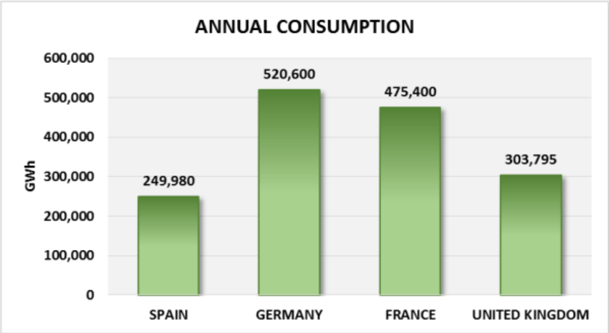


Figure 100: CO2 emissions, countries comparison. Source: Diverse



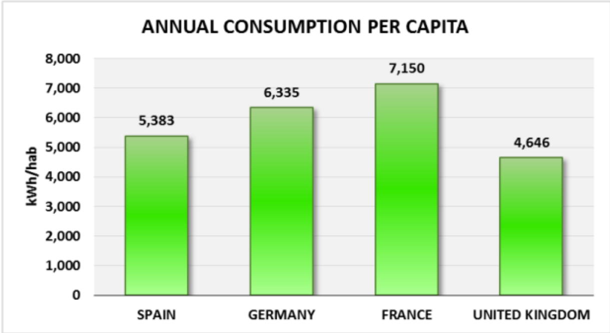
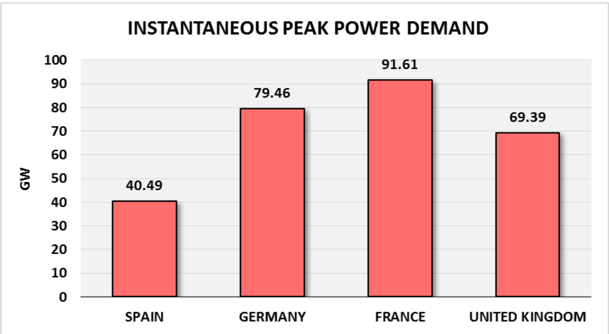


Figure 101: Annual consumption, countries comparison. Source: Diverse



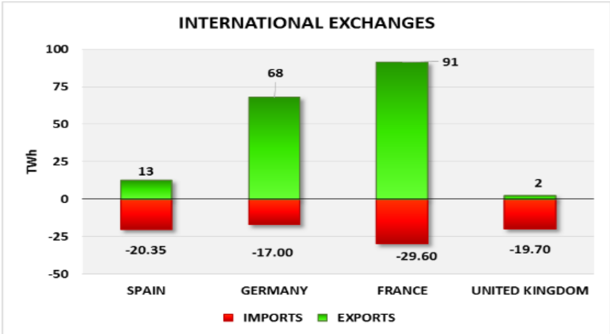


Figure 102: Peak power demand and intern. Exchanges, countries comparison. Source: Diverse

Year	SPAIN	GERMANY	FRANCE	THE UNITED KINGDOM[4]
2012	47.20	42.60	46.9	42.62
2013	44.30	37.80	43.20	40.74
2014	42.10	32.8	34.70	42.43
2015	50.30	31.6	38.50	50.79
2016	39.70	29.0	36.70	45.21

Figure 103: Daily market price (€/MWh), countries comparison. Source: Diverse

[4] The data for the United Kingdom is the average price of electricity

5.8 European Union

5.8.1 Generation

→ Net generating capacity and net generation

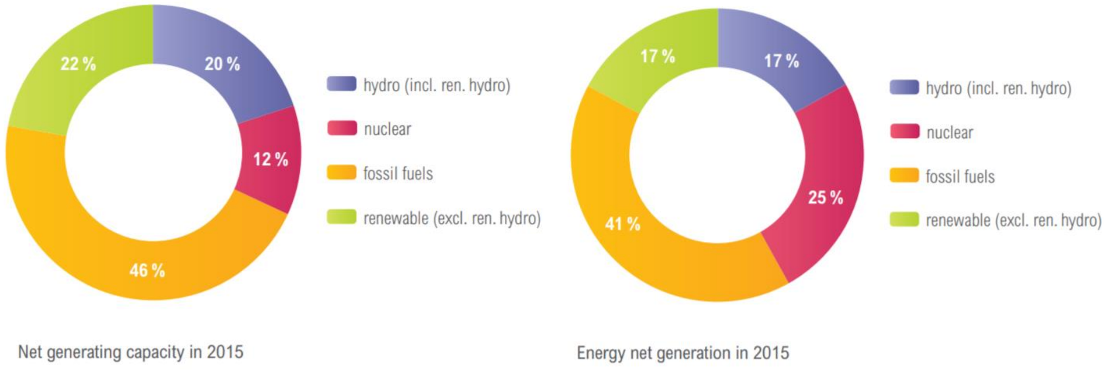


Figure 104: Net generation capacity and net generation, Europe. Source: Entsoe (37)

The graphs abov shows the net generating cpacity and the net generation of electricity respectivly for 2015. The data correspond to Entsoe countries[5]. The fossil fuels technology is the first source of electricity as much in cpacity as in the final generation.

→ EUROPEX Monthly energies 2015/2016

The next figures represent the energy exchanges by means of different countries associations grouped in EUROPEX in the years 2015 and 2016.

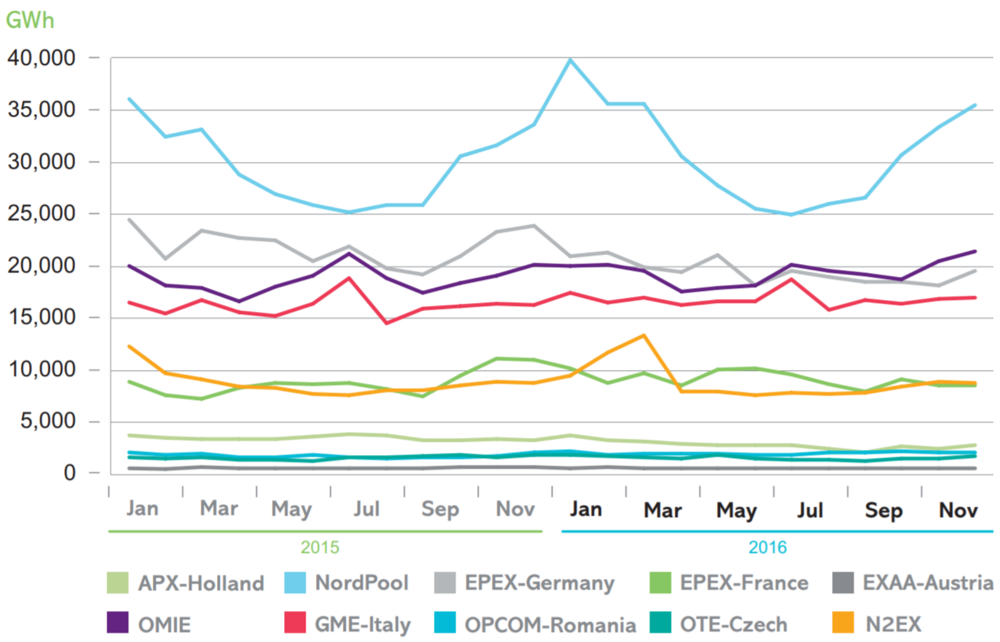


Figure 105: Monthly energy exchanges, Europe. Source: EUROPEX (38)

[5] https://www.entsoe.eu/about-entso-e/inside-entso-e/member-companies/Pages/default.aspx

→ Share of generation by means of type of electricity technology

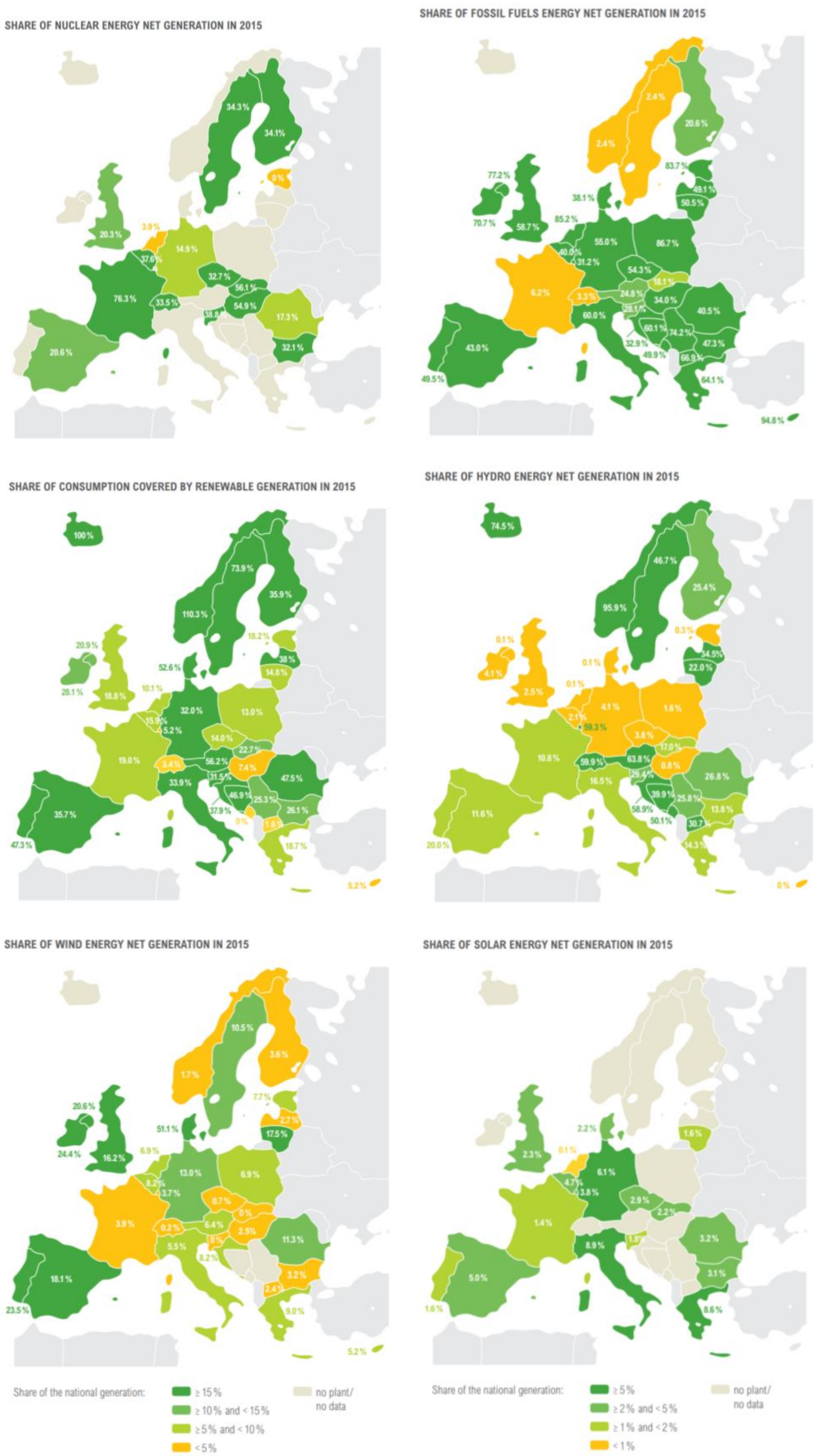


Figure 106: Share of generation by means of type of technology, Europe. Source: Entsoe (37)

The previous graphs represent share of generation by means of typeo of electricity technology for each europena country (Entsoe members) for the year 2015. Stands out for example the nuclear share in france or the hydro in some north countries like norway reaching values of 95%

→ **European Union capacity values by means of different technologies**

NUCLEAR CAPACITY GWh	2012	2013	2014	2015
EUROPEAN UNION 28 COUNTRIES	123,183	122,971	123,515	121,957

Figure 107: Nuclear capacity, Europe. Source: eurostat (39)

The table above shows the evolution of the nuclear capacity as the sum of all th countries in the European Union. The capacity remains constant, althought some east countris are constructing new nuclear plants after fukushima accident many others are finding a lot of diffivulties to continue with the nuclear program

FOSSIL FUELS CAPACITY[6] GWh	2012	2013	2014	2015
EUROPEAN UNION 28 COUNTRIES	452,827	438,274	438,131	423,241

Figure 108: Fossil fuels capacity, Europe. Source: eurostat (39)

The previous table shows the evolution of the fossil fuel capacity as the sum of all the countries in the European Union. More and more th fossil fuels technology due to the pollution, is lossing presence in the electricity sector in favour of green technologies as the renewables.

HYDRO CAPACITY GWh	2012	2013	2014	2015
EUROPEAN UNION 28 COUNTRIES	147,063	148,335	148,496	150,56

Figure 109: Hydro capacity, Europe. Source: eurostat (39)

The previous table shows the evolution of the hydro capacity as the sum of all the countries in the European Union. The hydro power plants are a kind old of renewable technology that mantains constant over the years because in many cases here is not more places to built more power plants.

5.8.2 Consumption

The next table shows the energy available for the final consumption for the European Union.

ENERGY AVAILABLE FOR THE FINAL CONSUMPTION GWh	2012	2013	2014	2015
EUROPEAN UNION[7]	2,767,737	2,792,836	2,707,013	2,742,482

Figure 110: Final consumption energy, Europe. Source: eurostat (39)

Electricity imports and electricity exports

GWh IMPORTED	2012	2013	2014	2015
EUROPEAN UNION	363,031	349,595	386,931	410,335

GWh EXPORTED	2012	2013	2014	2015
EUROPEAN UNION	344,368	336,983	371,433	396,076

Figure 111: Imports and exports, Europe. Source: eurostat (39)

---

6 Only main producers.

7 European Union represent the Europe of the 28 country members.

The previous tables collects the sum of the electricity imports and exports in the european unio from the year 2012 to year 2015. The net value increases every year at the same time a more and more interconnected europe in terms of electricity connexion becomes a reallity.

The balance as a result of adding both terms is the result of the electricity exchanged with non European Union countries.

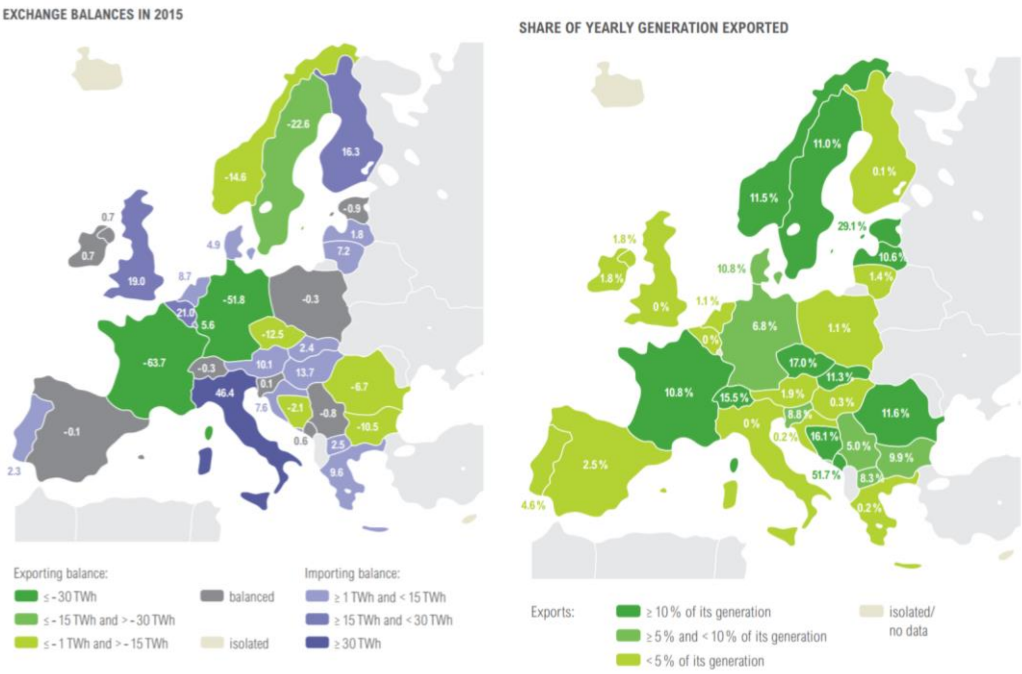


Figure 112: Exchange balance and share exported, Europe. Source: Entsoe (37)

The previous images are the exchange balance in the countries of the European Union for the year 2015 and the result of ths share of the yearly generation exported, the cuntries with 0% significate that theelectricity exported is not significance ovr the totl electricity production

→ Maximum Peak load

The next picture ilustrates the evolution of the maximum peak power demand of the European Union (Entsoe) during the years 2012 to 2015

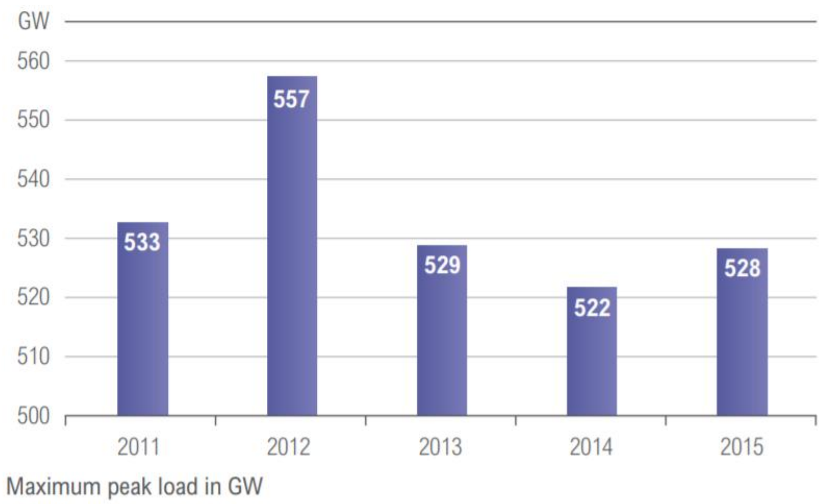


Figure 113: Maximum peak power demand, Europe. Source: Entsoe (37)

5.8.3 Market

The following tables, corresponds to the price of kWh (€/kWh) as the average of the European Union for domestic consumers(DC) and for industrial consumers (IC) both of the including all taxes and levies.

Band DC: 2500 kWh < Consumption < 5000 kWh

€/kWh	2012S1	2012S2	2013S1	2013S2	2014S1	2014S2	2015S1	2015S2	2016S1	2016S2
EUROPEANUNION	0.188	0.196	0.200	0.2024	0.2040	0.2075	0.2090	0.2103	0.2052	0.2054

Figure 114: Band DC, Europe. Source: eurostat (39)

Band IC: 500 MWh < Consumption < 2000 MWh

€/kWh	2012S1	2012S2	2013S1	2013S2	2014S1	2014S2	2015S1	2015S2	2016S1	2016S2
EUROPEAN UNION	0.1421	0.1438	0.1481	0.1468	0.1527	0.1498	0.1496	0.1472	0.1450	0.1416

Figure 115: Band IC, Europe. Source: eurostat (39)

The following europe image shows the average spot prices on power exchanges in 2015 and change vs 2014. It can be extracted the big difference between the " cheapest" countries and the most expensive ones. In term of numeric values, the difference between markets like Nord Pool or the reference market of germany with the markets like great britain or italy are practically the double in price.

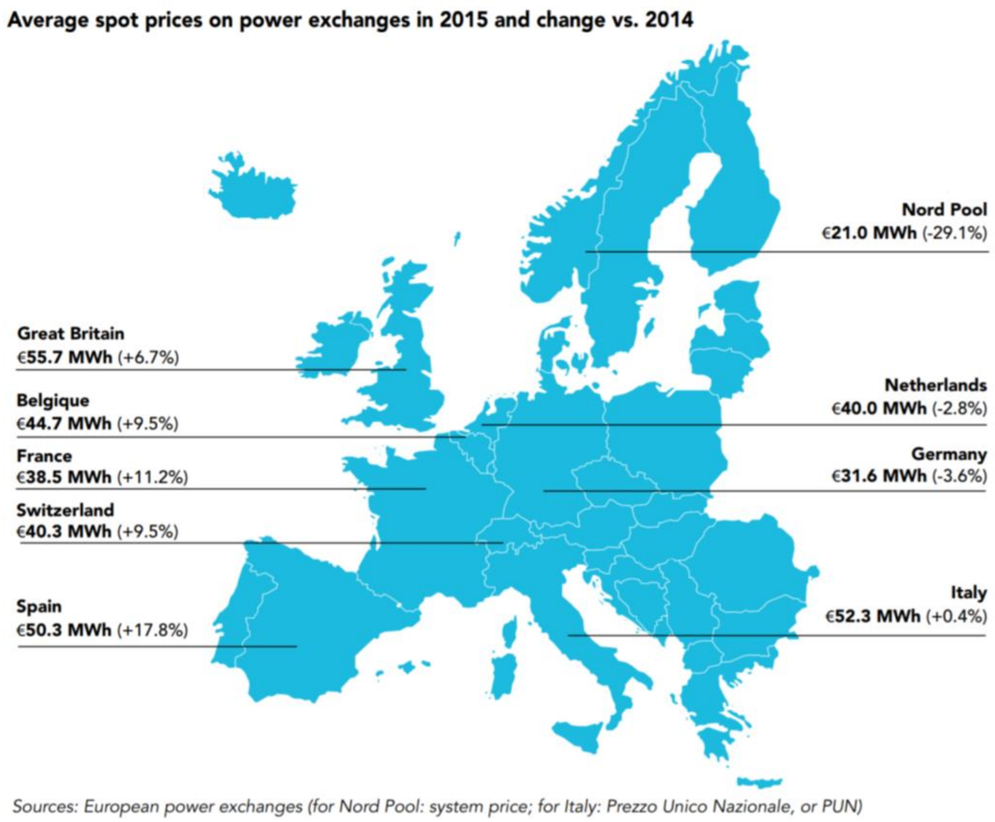


Figure 116: Average spot prices on power exchanges in 2015 and change vs 2014, Europe. Source: Rte (29)

The next graph (shows the difference in the spot price trends over 2011, 2012, 2013, 2014 and 2015 for the biggest electricity consumers in the European Union.

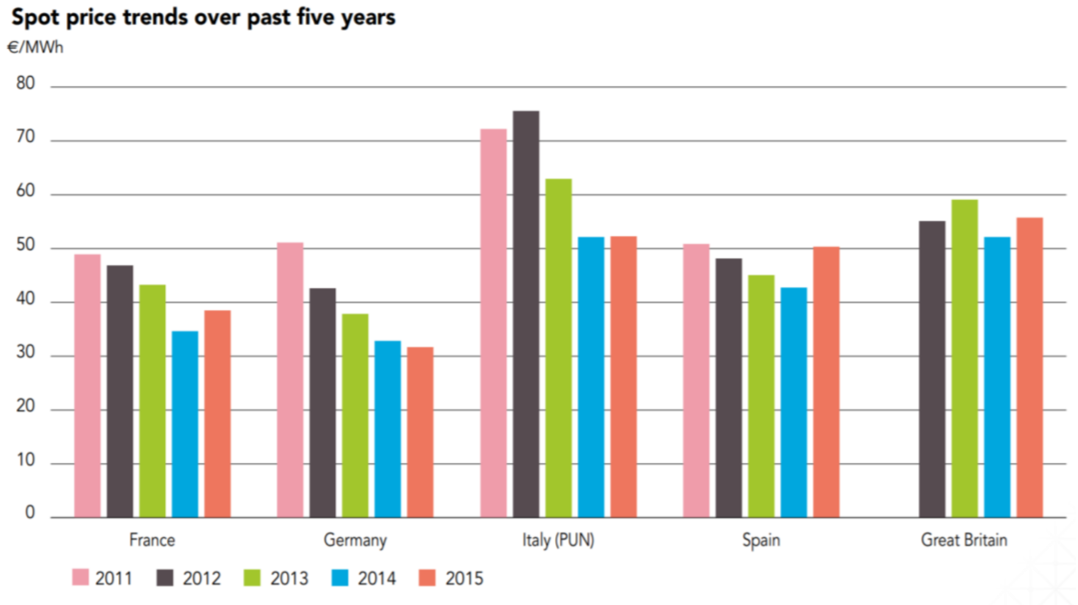


Figure 117: Spot price trend, Europe. Source: Source: Rte (29)

The next figures represent the average prices of different countries associations grouped in EUROPEX in the years 2015 and 2016.

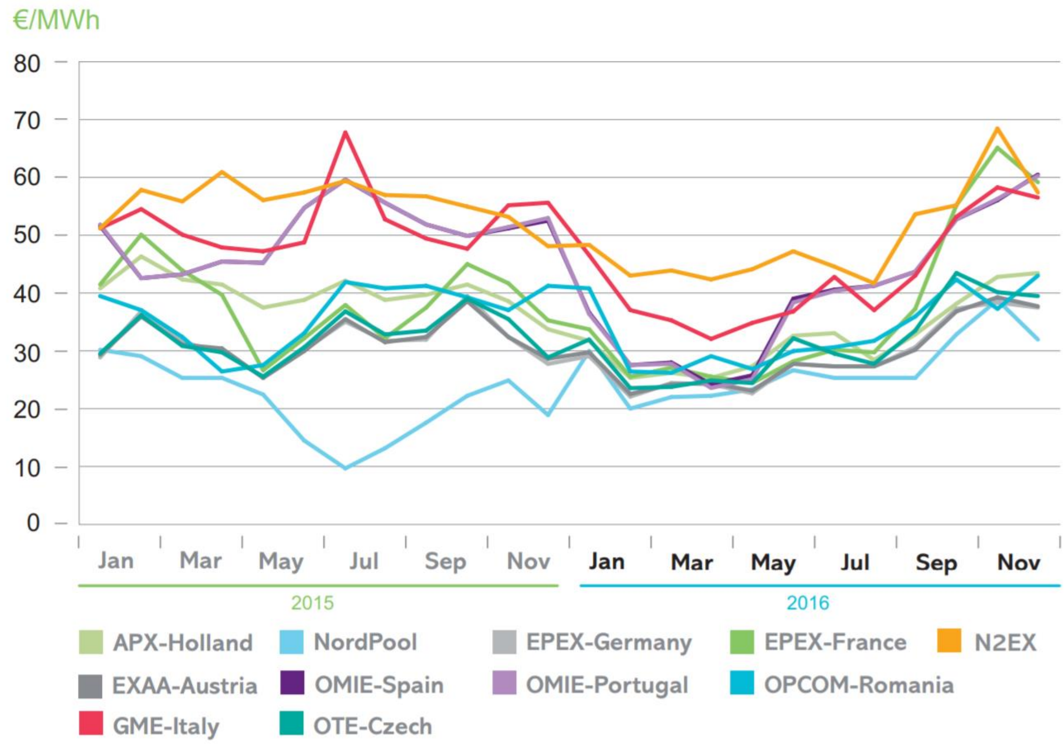


Figure 118: Monthly average prices, Europe. Source: EUROPEX (38)

Chapter 6.- COMPUTER TOOL

Once the concepts are developed the next step is the creation of a tool that could give access to all the resources.

For this purpose, the tool that is chosen is a web page due to its accessibility for general users as well as the fact that it is a fast source to all the content relative to all the indicators.

Thus, the webpage is designed with the web design creator “wix.com” (40), which allows to design and create webpages with a very intuitive interface for the user.

6.1 User guide

The webpage can be accessed by any computer or electronic tool as far as it is connected to the Internet, by introducing the URL: **indicadoreselectricoseuropa.com.**

The functioning, as a guide for any user, is explained underneath.

The first screen presents a Europe map in which those countries that the project has been based on are colored. These are: Spain, Germany, France and the United Kingdom, and also the European flag representing the European Union. At the right bottom there is a button where all information sources are listed and classified by country.

When clicking at any of the available countries, the screen will show the homepage of that specific country. In this screen there are four rectangles, each of them related to generation, consumption, network and markets. The top of this screen shows the flag of every country as well as an icon of a house, which are links to the rest of the countries and the homepage and will facilitate navigation amongst countries.

When selecting one of the rectangles (generation, consumption, network or markets), it will directly be displayed a list of the most representative electricity indicators of each item.

Furthermore, at the beginning of each page there is a link, “latest data”, which leads to the most updated documents by each of the institutions with the aim to provide the most recent available information.

Also, within each of lists there are links that will take the user to the real-time information of the system.

Finally, as an illustration of this, next chapter will present a case study with the aim to provide a better understanding of the computer tool by the user.

6.2 Case example

A practical example of the computer tool is underneath explained. The starting point is a case in which the user is interested in searching for the electrical indicators specifically for Germany and France. The user is looking for a comparison between the electrical generation of these two countries to see the electrical energy annual quantity produced and its distribution by the generation technologies.

The first step is to introduce the URL in a web searcher (www.indicadorselectricoseuropa.com). This is the homepage of the web that will be shown:

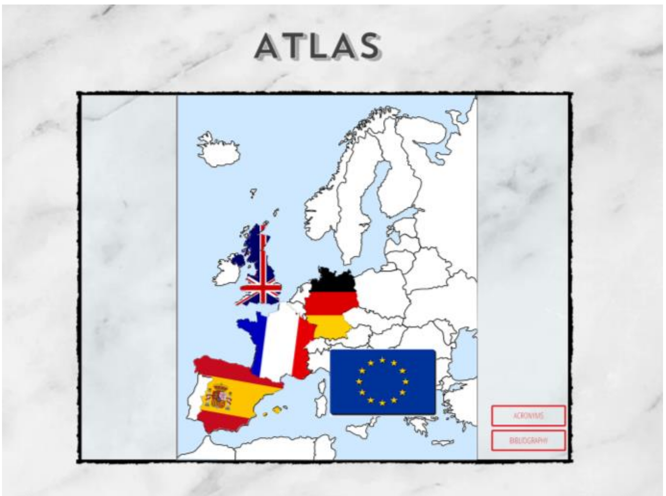


Figure 119: Webpage screenshot 1/6.

The user has to first click in France and the web page will direct him to the following screen:

Figure 120: Webpage screenshot 2/6.

Now, as the focus is the electrical generation, “generation” has to be clicked. This will lead to the next page, which is the homepage of Generation in France:

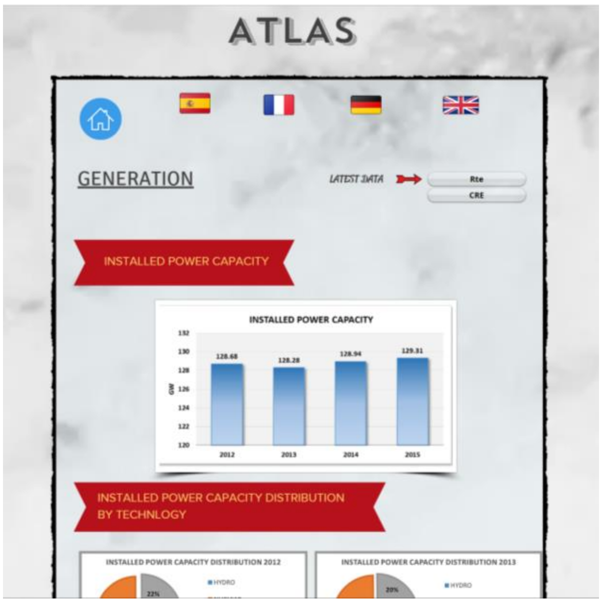


Figure 121: Webpage screenshot 3/6.

Once the user is here, he can check the most relevant indicators regarding electrical generation in France for the years 2012-2015 represented by a corresponding illustration or graph as well as access to the real time generation information provided by Rte-France by clicking in its logo.

Figure 122: Webpage screenshot 4/6.

Finally, with the aim that the web page does not become useless with time but that the user can access to the most recent data, there is a button at the top where the direct source of the information is shown as well as the latest articles and documents published by them.

Figure 123: Webpage screenshot 5/6.

Once this search has been done, the same steps would have to been followed in order to abstract the same information regarding Germany. For a faster process and use, in the top part of every page (except from the web homepage) there is a shortcut access for every country represented by each countries' flag, as well as a shortcut to the web homepage.

Figure 124: Webpage screenshot 6/6.

Chapter 7.- ACTIVITIES SCHEDULE

The Project was started in February and its duration accounts for 7 and a half months (30 weeks). The work was carried out simultaneously with university classes, so there is not a standard timing of hours per day, but it is estimated that implied a total of 400 working hours (14 hours per week approximately).

The following table shows the activities that were accomplished each week:

ACTIVITIES BREAKDOWN				
#	ACTIVITY	STARTING WEEK	FINAL WEEK	DURATION WEEKS
A	GET TFG INFORMATION	1	1	1
B	SEARCH FOR PRECEDDENTS	1	3	3
C	SEARCH FOR DOCUMENTATION	3	26	24
D	WRITE Chapter 3.- Electric system in Spain	5	8	4
E	WRITE Chapter 4.- Electrical indicators	8	14	7
F	WRITE Chapter 5.- Atlas development	14	22	9
G	COMPUTER TOOL	20	27	8
H	WRITE Chapter 6.- Computer tool	22	24	3
I	WRITE Chapter 8.- and Chapter 9.- Conclusions	24	26	3
J	WRITE Chapter 10.- Bibliography and Chapter 12.- Appendices	27	28	2
K	WRITE Chapter 7.- Activities schedule	28	28	1
L	CHECK PROJECT	28	30	2

Figure 125: Activities breakdown.

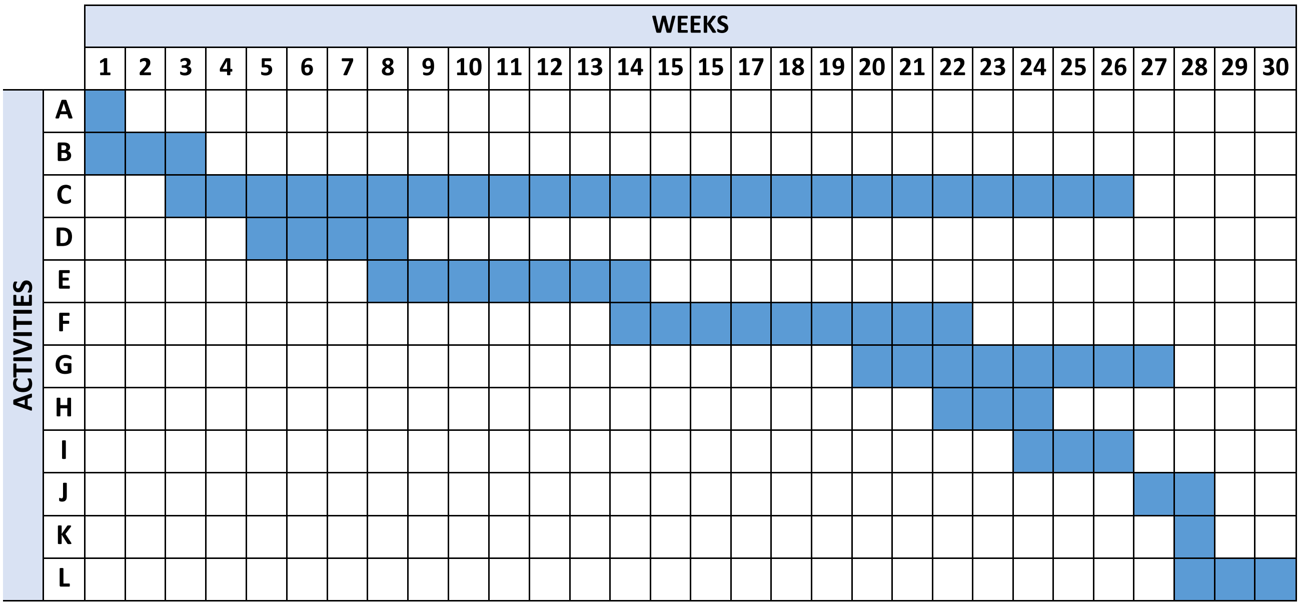


Figure 126: Gantt diagram.

Chapter 8.- COSTS

The next table represent a brief summary of the TFG costs.

<table>
<tr><td>Author</td><td colspan="3">Javier Pollos Ezquerra</td></tr>
<tr><td>Location</td><td colspan="3">UC3M Leganés</td></tr>
<tr><td colspan="4">Project description</td></tr>
<tr><td>Title</td><td colspan="3">Atlas of electrical indicators published in Spain and the EU</td></tr>
<tr><td>Duration</td><td colspan="3">7.5 months</td></tr>
<tr><td colspan="4">Costs breakdown</td></tr>
<tr><td colspan="4">HR cost</td></tr>
<tr><td>Category</td><td>Duration(hours)</td><td>Salary (€/h)</td><td>Cost (€)</td></tr>
<tr><td>Junior engineer</td><td>400</td><td>10,00</td><td>4,000 €</td></tr>
<tr><td colspan="4">Computer tool cost</td></tr>
<tr><td>Category</td><td>Price (€)</td><td>Amortization (€)</td><td>Cost (€)</td></tr>
<tr><td>Personal computer</td><td>800</td><td>138.71[8]</td><td>138.71</td></tr>
<tr><td>Webpage (URL design.)</td><td>56.54</td><td>-</td><td>56.54</td></tr>
<tr><td colspan="4">Summary</td></tr>
<tr><td>Concept</td><td>Cost (€)</td><td colspan="2">TOTAL</td></tr>
<tr><td>HR</td><td>4000</td><td colspan="2" rowspan="2">4,195.25 € + IVA</td></tr>
<tr><td>Computer tool</td><td>195.25</td></tr>
</table>

[8] $800€ * \frac{200\ days}{3*365\ useful\ life\ days} = 138.71€$

Chapter 9.- CONCLUSIONS

9.1 Technical conclusions

First of all, with respect to the fulfillment of the objectives proposed when starting this project, they are considered satisfactorily achieved. These are:

- Presenting and overview of the most important electric components in order to describe an electrical system.
- To stand out the most significate indicators of the electric system.
- To implement a web page where users can find the figures and information of the electric system of Spain, France Germany and the United Kingdom.

A compilation of electrical indicators has been presented. These have first been described with the purpose of understanding their meaning and implications, being classified by four main categories, which are: generation, networks, consumption and market. They have next been calculated, for several countries, by focusing on Europe, for a certain time period with the aim to illustrate them as well as to make an analysis of the figures.

- It has been showed through the chosen quantitative indicators that generation differs across countries as it is very dependent on its energetic tradition and econosistem. In this sense, France has a higher capacity to generate nuclear energy, while the United Kingdom generation lays especially on carbon and the north of Europe on hydro.
- Regarding the network, countries are becoming even more interconnected as long as the geography (seas and mountains) does not make it impossible. This way, Spain is for instance connected to Poland, so energy consumed in Spain could have been generated in Poland and vice versa.
- In terms of demand, for example French annual electricity consumption without the crisis is slowly increasing: while the system demands for more and more energy, efficiency in its consumption is also going up, so the consumption of energy increases in a progressive way.
- With respect to the markets, it has been showed that electricity price gaps are getting reduced towards a more homogeneous figure across countries. Each country presents its own pricing in the sense those prices are very influenced by local taxes, but the fact that the interconnections capacity is raising makes generation prices to become more equal narrowing the gap amongst countries.

Focusing in Spain, the reference country in this study, it is important to emphasize some interesting ideas extracted from the indicators. The generation electricity in Spain depends on different technologies with any of them over 30% of the total production (a very mixed generation). The electrical grid is high developed, although the difficulties in the interconnections capacity with the rest of Europe by the Pyrenees makes not comparable with other countries yet. As it occurs with other European countries, the demand in Spain grows every year in progressive way. The markets prices are different from other EU countries although the trend is to reduce the gap between them. The information can be found in internet, is public and it is usually found in different languages (CNMC, REE, OMIE).

Thus, these facts are observed by looking at the indicators that are included in each category. Electrical indicators reveal the need of information to be accurately classified and understood, so that improvement in the field of electricity can be successfully achieved. Comparing between countries which have similar demographic, geographic and development characteristics may provide with clues and signs that more efficiency shall be achieved in a certain field, or may help to point out and to reason the differences existing between each other.

All in all, information is essential for carrying any analysis and investigation for further growth of the society. It has to be accurate, understandable and comparable. Choosing certain specific indicators helps with this task, by providing a quantitative measure that can be compared and analyzed.

Also, availability is another essential feature. It may occur that the information is hard to find or that it is disperse in many sources making it difficult to be found and raised conclusions from. Only a few European institution follow the same pattern when analyzing different countries among which are Eurostat, ACER or Entsoe. This is why the webpage has been designed and implemented, so that users can access to it easily as well as keep updated with it. The webpage aim is to be an open tool for future analysis, research or curiosity of the user.

Research in the electrical field is fundamental as, even though it has considerably changed in the last decades, it still imposes challenges and room for improvement. More countries shall be included in the analysis as well as longer time series so that the outcomes obtained can be used for more purposes.

9.2 Personal conclusions

From a personal point of view, carrying out this project has been the end of my academic background as so far in the Electrical Engineering at Carlos III de Madrid University. Electricity is closely related to the field of energy and this is why I found it as an interesting area to focus on and to apply all the knowledge acquired during the studies on Energy.

During the realization of the project I have learnt several lessons. On the one hand, I have realized that information is a powerful tool as it is the basis for change and development. Sometimes there is data that can be calculated or observed from different points of view, so understanding the meaning of each indicator is essential for comparing and improving in this field as well as in any other. I have needed to contrast several sources of information in order to obtain those which are the most comparable and useful for future research and practical appliance. With the aim of obtaining and understanding the data provided by the national organisms, I got in contact with several of them and they provided me with this information, which helped me to gain experience and learn about the agents that are concerned in the process.

On the other hand, I have been able to observe the change that is nowadays happening both in Spain and in Europe in regards with the electricity field: electricity is being approached not only from the consumption side, as a final product, but the process that takes place since its generation and production is more and more relevant. As an illustration of this we find the generation by means of renewable energies and the improved transmission and distribution systems within a more connected European continent.

Finally, I am sure that this project will help as a cornerstone for my next steps as it has provided me with new knowledge and has become a part of my experience for facing new challenges in the future.

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Chapter 11.- ACRONYMS LIST

ACER	Agency for the Cooperation of Energy Regulators
AIT	Average Interruption Time
BKartA	Bundeskartellamt
BNetzA	Bundesnetzagentur
BOE	Boletín Oficial del Estado
CNMC	Comisión Nacional de los Mercados y la Competencia
CNMV	Comisión Nacional del Mercado de Valores
CRE	Commission de régulation de l'énergie
DC	Domestic Consumers
DECC	Department of Energy & Climate Change
DEHSt	Deutsche Emissionshandelsstelle
DETI	Department of Enterprise, Trade and Investment in Northern Ireland
DGCCRF	Direction générale de la concurrence, de laconsommationetdelarépressiondesfraudes
DNO	Distribution Network Operators
DSO	Distribution System Operator
EDF	Électricité De France
EEG	Erneuerbare-Energien-Gesetz
EEX	European Energy Exchange
ENS	Energy Not Supplied
ENTSOE	European Network of Transmission System Operators for Electricity
EnWG	Energiewirtschaftsgesetz
EUROPEX	European Energy Exchanges
GB	Great Britain
GEMA	Gas and Electricity Markets Authority
HSE	Health and Safety Executive
IC	Industrial Consumers
MIBEL	Mercado Ibérico de la Electricidad
MINETAD	Ministerio de Energía, Turismo y Agenda Digital
MNE	Médiateur National de l'Energie
MTS	Markttransparenzstelle
NGET	National Grid Electricity Transmission
OFGEM	Office of Gas and Electricity Markets
OMIE	Operador del Mercado Ibérico de Energía - Polo Español
OMIP	Operador del Mercado Ibérico de Energía - Polo Portugués
ONR	Office for Nuclear Regulation
REE	Red Eléctrica de España
RTE	Réseau de transport d'électricité
TSO	Transmission System Operator
UBA	Umweltbundesamt
UK	United Kingdom
UR	Utility Regulator

Chapter 12.- APPENDICES

12.1 Local legislation

SPAIN

- Real Decreto 1074/2015, de 27 de noviembre, por el que se modifican distintas disposiciones en el sector eléctrico
- Ley 3/2014, de 27 de marzo, por la que se modifica el texto refundido de la Ley General para la Defensa de los Consumidores y Usuarios y otras leyes complementarias, aprobado por el Real Decreto Legislativo 1/2007, de 16 de noviembre.
- Ley 24/2013, de 26 de diciembre, del Sector Eléctrico.
- Real Decreto 198/2010, de 26 de febrero, por el que se adaptan determinadas disposiciones relativas al sector eléctrico a lo dispuesto en la Ley 25/2009, de modificación de diversas leyes para su adaptación a la ley sobre el libre acceso a las actividades de servicios y su ejercicio.
- Ley 18/2008, del 23 de diciembre, de garantía y calidad del suministro eléctrico
- Real Decreto 1110/2007, de 24 de agosto, por el que se aprueba el Reglamento unificado de puntos de medida del sistema eléctrico.
- Ley 17/2007, de 4 de julio, por la que se modifica la Ley 54/1997, de 27 de noviembre, del Sector Eléctrico, para adaptarla a lo dispuesto en la Directiva 2003/54/CE, del Parlamento Europeo y del Consejo, de 26 de junio de 2003, sobre normas comunes para el mercado interior de la electricidad.
- Real Decreto 661/2007, de 25 de mayo, por el que se regula la actividad de producción de energía eléctrica en régimen especial.
- Orden ECO/797/2002, de 22 de marzo, por la que se aprueba el procedimiento de medida y control de la continuidad del suministro eléctrico.
- Real Decreto 1955/2000, de 1 de diciembre, por el que se regulan las actividades de transporte, distribución, comercialización, suministro y procedimientos de autorización de instalaciones de energía eléctrica.
- Ley 54/1997, de 27 de noviembre, del sector eléctrico.
- Decreto 351/1987, de 23 de noviembre, por el que se determinan los procedimientos administrativos aplicables a las instalaciones eléctricas.

12.2 European legislation

GENERAL REGULATION OF THE ELECTRICAL SECTOR

- COM/2015/0080 Comunicación de la Comisión al Parlamento Europeo, al Consejo, al Comité Económico y Social Europeo, al Comité de las Regiones y al Banco Europeo de Inversiones. Estrategia Marco para una Unión de la Energía resiliente con una política climática prospectiva.
- COM/2016/0860 Comunicación de la Comisión al Parlamento Europeo, al Consejo, al Comité Económico y Social Europeo, al Comité de las Regiones y al Banco Europeo de Inversiones. Energía limpia para todos los europeos.

GENERATION

- Directiva 2005/89/CE del Parlamento Europeo y del Consejo de 18 de enero de 2006 sobre las medidas de salvaguarda de la seguridad del abastecimiento de electricidad y la inversión en infraestructura

TRANSMISSION AND DISTRIBUTION

- Reglamento (UE) No 347/2013 del Parlamento Europeo y del Consejo de 17 de abril de 2013 relativo a las orientaciones sobre las infraestructuras energéticas transeuropeas
- Reglamento (CE) nº 714/2009 del Parlamento Europeo y del Consejo de 13 de julio de 2009 relativo a las condiciones de acceso a la red para el comercio transfronterizo de electricidad y por el que se deroga el Reglamento (CE) no 1228/2003
- Directiva 2005/89/CE del Parlamento Europeo y del Consejo de 18 de enero de 2006 sobre las medidas de salvaguarda de la seguridad del abastecimiento de electricidad y la inversión en infraestructura

MARKET AND PAYMENT

- Reglamento (UE) nº 1227/2011 del Parlamento Europeo y del Consejo, de 25 de octubre de 2011, sobre la integridad y la transparencia del mercado mayorista de la energía.
- Directiva 2008/92/CE del Parlamento Europeo y del Consejo, de 22 de octubre de 2008 , relativa a un procedimiento comunitario que garantice la transparencia de los precios aplicables a los consumidores industriales finales de gas y de electricidad

ENERGY EFFICIENCY

- Reglamento Delegado (UE) 2015/2402 de la Comisión, de 12 de octubre de 2015, por el que se revisan los valores de referencia de la eficiencia armonizados para la producción por separado de calor y electricidad, de conformidad con lo dispuesto en la Directiva 2012/27/UE del Parlamento Europeo y el Consejo, y por el que se deroga la Decisión de Ejecución 2011/877/UE de la Comisión
- Anexo a la Directiva 2012/27/UE
- Directiva 2012/27/UE del Parlamento Europeo y del Consejo del 25 de octubre de 2012 relativa a la eficiencia energética, por la que se modifican las Directivas 2009/125/CE y 2010/30/UE, y por la que se derogan las Directivas 2004/8/CE y 2006/32/CE.
- Regulación Directiva 2010/31/UE - Marco metodológico comparativo para calcular los niveles óptimos de rentabilidad de los requisitos mínimos de eficiencia energética de los edificios y de sus elementos.

- Directiva 2010/31/UE del parlamento europeo y del consejo, de 19 de mayo de 2010 relativa a la eficiencia energética de los edificios.
- Directiva 2010/30/UE del Parlamento Europeo y del Consejo de 19 de mayo de 2010 relativa a la indicación del consumo de energía y otros recursos por parte de los productos relacionados con la energía, mediante el etiquetado y una información normalizada.
- Directiva 2009/125/CE del Parlamento Europeo y del Consejo de 21 de octubre de 2009 por la que se instaura un marco para el establecimiento de requisitos de diseño ecológico aplicables a los productos relacionados con la energía.
- Directiva 2009/28/CE del Parlamento Europeo y del Consejo de 23 de abril de 2009 relativa al fomento del uso de energía procedente de fuentes renovables y por la que se modifican y se derogan las Directivas 2001/77/CE y 2003/30/CE.
- Directiva 2002/91/CE del Parlamento Europeo y del Consejo de 16 de diciembre de 2002 relativa a la eficiencia energética de los edificios.

12.3 Market tables

SPAIN

	NUMBER OF CONSUMERS			
	2012	**2013**	**2014**	**2015**
BT (< 1 kV)	25,966,683	25,726,805	25,772,983	25,754,982
AT 1 (≥ 1 kV y < 36 kV)	100,856	99,891	99,793	101,204
AT 2 (≥ 36 kV y < 72.5 kV)	1,618	1,593	1,585	1,595
AT 3 (≥ 72.5 kV y < 145 kV)	422	423	418	423
AT 4 (≥ 145 kV)	515	546	579	588
TOTAL	26,070,093	25,829,258	25,875,358	25,858,792

	AVERAGE SIZE (MWh/customer)			
	2012	**2013**	**2014**	**2015**
BT (< 1 kV)	4.12	3.95	3.75	3.82
AT 1 (≥ 1 kV y < 36 kV)	667	652	661	666
AT 2 (≥ 36 kV y < 72.5 kV)	10,042	10,121	10,535	10,625
AT 3 (≥ 72.5 kV y < 145 kV)	20,988	21,404	23,609	24,315
AT 4 (≥ 145 kV)	44,537	42,931	41,413	41,372
TOTAL	8.52	8.34	8.24	8.40

ACCESS TARIFF LOW VOLTAGE (< 1 kV)

	WITHOUT DISCRIMINATION		WITH DISCRIMINATION		WITH DISCRIMINATION SUPERVALLEY	
	TARIFF 2.0A		**TARIFF 2.0DHA**		**TARIFF 2.0DHS**	
	TPA €/kW and year	TEA €/kWh	TPA €/kW and year	TEA €/kWh	TPA €/kW and year	TEA €/kWh
Power ≤ 10 kW	38,043,426	0,044027	38,043,426	P1: 0,062012 P2: 0,002215	38,043,426	P1:0,062012 P2:0,002879 P3:0,000886

	WITHOUT DISCRIMINATION		WITH DISCRIMINATION		WITH DISCRIMINATION SUPERVALLEY	
	TARIFF 2.1A		**TARIFF 2.1DHA**		**TARIFF 2.1DHS**	
	TPA €/kW y year	TEA €/kWh	TPA €/kW y year	TEA €/kWh	TPA €/kW y year	TEA €/kWh
Power > 10 kW ≤ 15 kW	44,444,710	0,05736	44,444,710	P1:0,074568 P2: ,013192	44,444,710	P1: 0,074568 P2: 0,017809 P3: 0,006596

	WITH DISCRIMINATION	
	TARIFF 3.0A	
	TP €/kW y year	TE €/kWh
Power > 15 kW	P1:40,728885 P2:24,437330 P3:16,291555	P1:0,018762 P2:0,012575 P3:0,004670

ACCESS TARIFF HIGH VOLATGE (> 1 kV y < 36 kV; Contracted Power > 450 kW).

TARIFF 3.1ª	
TP €/kW and year	**TE €/kWh**
P1: 59,173468	P1: 0,014335
P2: 36,490689	P2: 0,012754
P3: 8,3677310	P3: 0,007805

HIGH VOLATGE TARIFF: 6 TARIFF PERIODS						
	TARIFF 6.1A (> 1 KV and < 30 kV)		**TARIFF 6.1B (> 30 KV and < 36 kV)**		**TARIFF 6.2 (> 36 KV and < 72 kV)**	
	TP €/kW and year	TE €/kWh	TP €/kW and year	TE €/kWh	TP €/kW and year	TE €/kWh
P1	39,139,427	0,026674	31,020,989	0,021822	22,158,348	0,015587
P2	19,586,654	0,019921	31,020,989	0,016297	11,088,763	0,011641
P3	14,334,178	0,010615	11,360,932	0,008685	8,115,134	0,006204
P4	14,334,178	0,005283	11,360,932	0,004322	8,115,134	0,003087
P5	14,334,178	0,003411	11,360,932	0,002791	8,115,134	0,001993
P6	6,540,177	0,002137	5,183,592	0,001746	3,702,649	0,001247
	TARIFF 6.3 (72,5 KV y < 145 kV)		**TARIFF 6.4 (145 kV)**		**TARIFF 6.5 (international connexions)**	
	TP €/kW and year	TE €/kWh	TP €/kW and year	TE €/kWh	TP €/kW and year	TE €/kWh
P1	18,916,198	0,015048	13,706,285	0,008465	13,706,285	0,008465
P2	9,466,286	0,011237	6,859,077	0,007022	6,859,077	0,007022
P3	6,927,750	0,005987	5,019,707	0,004025	5,019,707	0,004025
P4	6,927,750	0,002979	5,019,707	0,002285	5,019,707	0,002285
P5	6,927,750	0,001924	5,019,707	0,001475	5,019,707	0,001475
P6	3,160,887	0,001206	2,290,315	0,001018	2,290,315	0,001018

GERMANY

Supplier switches by consumer category in 2015

Final consumer category	Number of meter points where the supplying legal entity changed in 2015	Percentage of all meter points in this category	Consumption at meter points where the supplier changed	Percentage of total consumption by consumer category
< 10 MWh/year	3,100,746	6.6 %	8.9 TWh	7.5 %
10 MWh/year – 2 GWh/year	205,653	10.3 %	15.5 TWh	12.8 %
> 2 GWh/year	2,878	15.4 %	28.5 TWh	12.5 %

Average volume weighted price per tariff for household customers with an annual consumption below 1,000 kWh (band I; Eurostat band DA) as of 1 April 2016 (ct/kWh)

Price component	Default tariff	Contract with the default supplier outside of default supply contracts	Special tariff with other supplier
Energy procurement, supply, other costs and margin	11.74	6.34	7.89
Net network charge	9.52	8.42	10.68
Billing charge	2.16	1.83	1.70
Metering charge	0.60	0.61	0.51
Meter operation charge	1.71	1.48	1.38
Concession fee	1.78	1.77	1.52
Renewable energy surcharge	6.35	6.35	6.35
CHP surcharge	0.45	0.45	0.45
Section 19 surcharge	0.38	0.38	0.38
Offshore liability surcharge	0.04	0.04	0.04
Electricity tax	2.05	2.05	2.05
Value added tax	6.98	10.06	6.26
Total	**43.73**	**39.77**	**39.21**

Average volume weighted price per tariff for household customers with an annual consumption between 1,000 kWh and 2,500 kWh (band I; Eurostat band DB) as of 1 April 2016 (ct/kWh)

Price component	Default tariff	Contract with the default supplier outside of default supply contracts	Special tariff with other supplier
Energy procurement, supply, other costs and margin	8.60	7.17	6.35
Net network charge	6.62	6.24	7.31
Billing charge	0.67	0.61	0.56
Metering charge	0.19	0.20	0.16
Meter operation charge	0.54	0.50	0.46
Concession fee	1.78	1.76	1.55
Renewable energy surcharge	6.35	6.35	6.35
CHP surcharge	0.45	0.45	0.45
Section 19 surcharge	0.38	0.38	0.38
Offshore liability surcharge	0.04	0.04	0.04
Electricity tax	2.05	2.05	2.05
Value added tax	5.25	4.89	4.88
Total	**32.91**	**30.62**	**30.52**

Average volume weighted price per tariff for household customers with an annual consumption between 2,500 kWh and 5,000 kWh (band III; Eurostat band DC) as of 1 April 2016 (ct/kWh)

Price component	Default tariff	Contract with the default supplier outside of default supply contracts	Special tariff with other supplier
Energy procurement, supply, other costs and margin	8.06	6.74	5.90
Net network charge	6.00	6.13	6.40
Billing charge	0.35	0.31	0.31
Metering charge	0.09	0.08	0.08
Meter operation charge	0.27	0.24	0.22
Concession fee	1.72	1.62	1.49
Renewable energy surcharge	6.35	6.35	6.35
CHP surcharge	0.45	0.45	0.45
Section 19 surcharge	0.38	0.38	0.38
Offshore liability surcharge	0.04	0.04	0.04
Electricity tax	2.05	2.05	2.05
Value added tax	4.89	4.63	4.50
Total	**30.63**	**29.01**	**28.17**

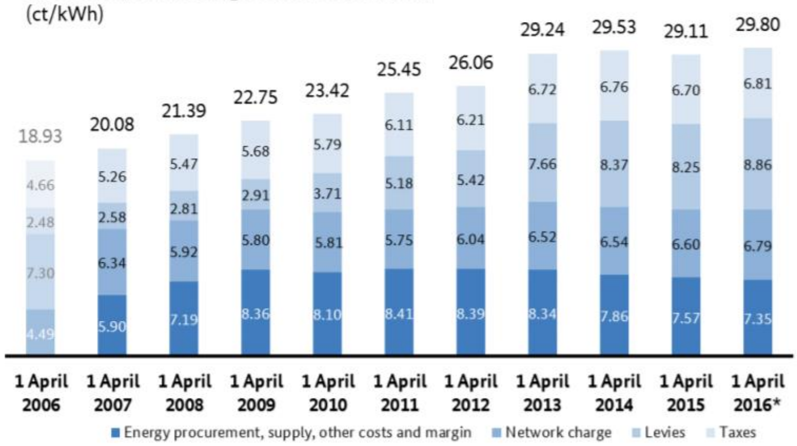
Average volume weighted price per tariff for household customers with an annual consumption between 5,000 kWh and 10,000 kWh (band IV) as of 1 April 2016 (ct/kWh)

Price component	Default tariff	Contract with the default supplier outside of default supply contracts	Special tariff with other supplier
Energy procurement, supply, other costs and margin	7.52	5.78	5.55
Net network charge	5.58	5.43	6.02
Billing charge	0.17	0.17	0.16
Metering charge	0.05	0.06	0.05
Meter operation charge	0.15	0.16	0.13
Concession fee	1.75	1.72	1.49
Renewable energy surcharge	6.35	6.35	6.35
CHP surcharge	0.45	0.45	0.45
Section 19 surcharge	0.38	0.38	0.38
Offshore liability surcharge	0.04	0.04	0.04
Electricity tax	2.05	2.05	2.05
Value added tax	4.65	4.29	4.30
Total	**29.12**	**26.87**	**26.96**

Average volume weighted price across all tariffs for household customers with an annual consumption between 2,500 kWh and 5,000 kWh (band III; Eurostat band DC) as of 1 April 2016 (ct/kWh)

Price component	Volume weighted average across all tariffs (ct/kWh)	Percentage of total price (%)
Energy procurement, supply, other costs and margin	7.35	24.7
Net network charge	6.11	20.5
Billing charge	0.34	1.1
Metering charge	0.09	0.3
Meter operation charge	0.25	0.8
Concession fee	1.65	5.5
Renewable energy surcharge	6.35	21.3
CHP surcharge	0.45	1.5
Section 19 surcharge	0.38	1.3
Offshore liability surcharge	0.04	0.1
Electricity tax	2.05	6.9
Value added tax	4.76	16.0
Total	**29.80**	**100**

Electricity price for household customers with an annual consumption of 3,500 kWh (volume weighted across all tariffs)
(ct/kWh)



*Based on the band for an annual consumption of between 2,500 and 5.000 kWh .